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Viola et al.

[11] **4,424,500**
[45] **Jan. 3, 1984**

[54] BEAM FORMING NETWORK FOR A MULTIBEAM ANTENNA

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[73] Assignee: **Sperry Corporation**, New York, N.Y.

[21] Appl. No.: **220,228**

[22] Filed: **Dec. 29, 1980**

[51] **Int. Cl.**^{3} **H01P 3/08**; H01P 5/12
[52] **U.S. Cl.** **333/128**; 333/26; 333/33; 333/246; 343/373
[58] **Field of Search** ... 343/100 SA, 854, 700 MS File; 333/116, 128, 26, 33, 246

[56] **References Cited**

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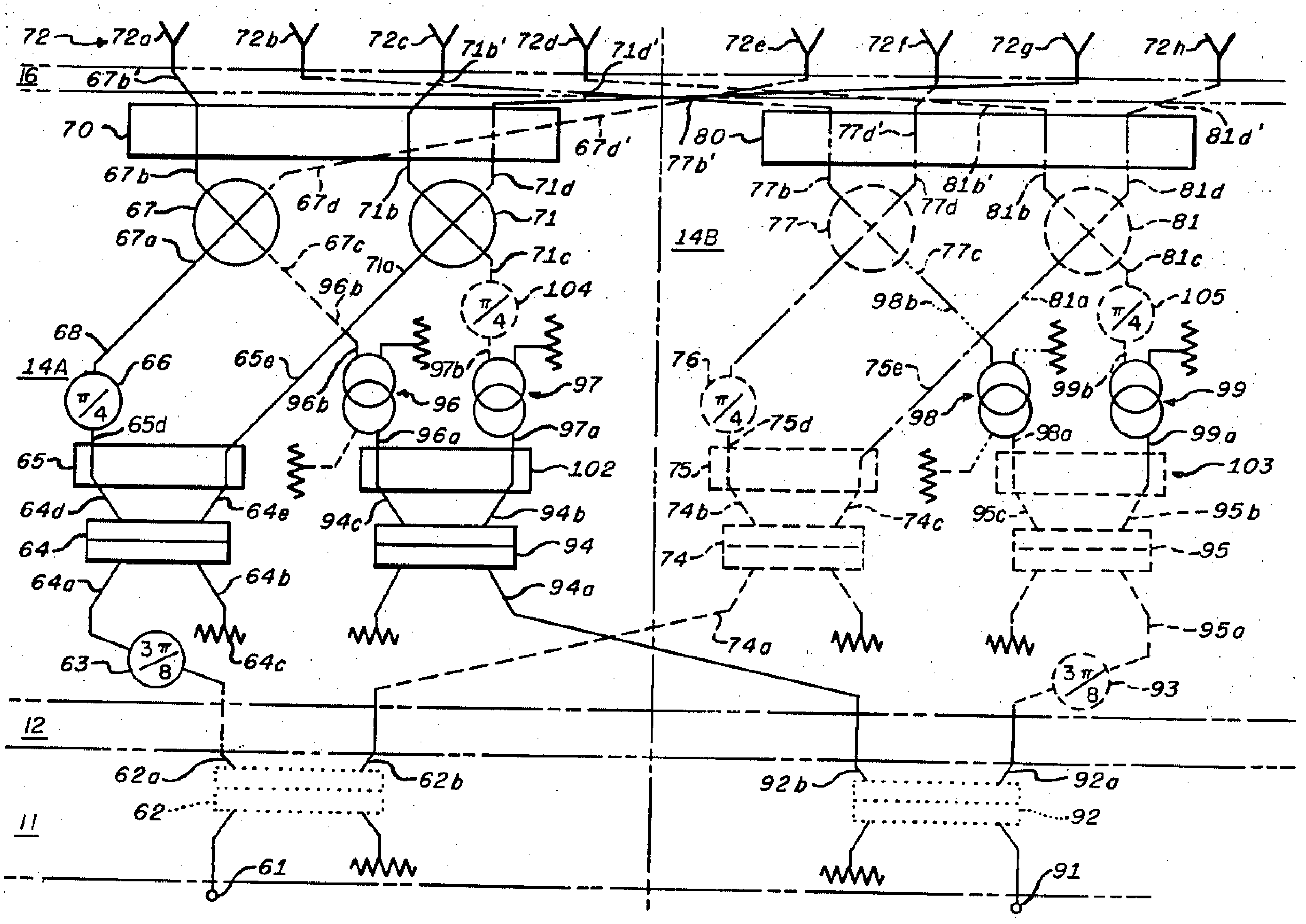
Primary Examiner—Theodore M Blum
Attorney, Agent, or Firm—Howard P. Terry; Seymour Levine

[57] ABSTRACT

A beam forming network comprising multi-deck circuitry with a plurality of levels within each deck formed by asymmetric striplines having a multiplicity of inner conductor levels. Interlevel coupling is accomplished with 3 dB couplers which power split signals incident thereto between transmission line levels and 0 dB interlevel couplers which transfer signals from one level to another without significant attenuation.

7 Claims, 26 Drawing Figures



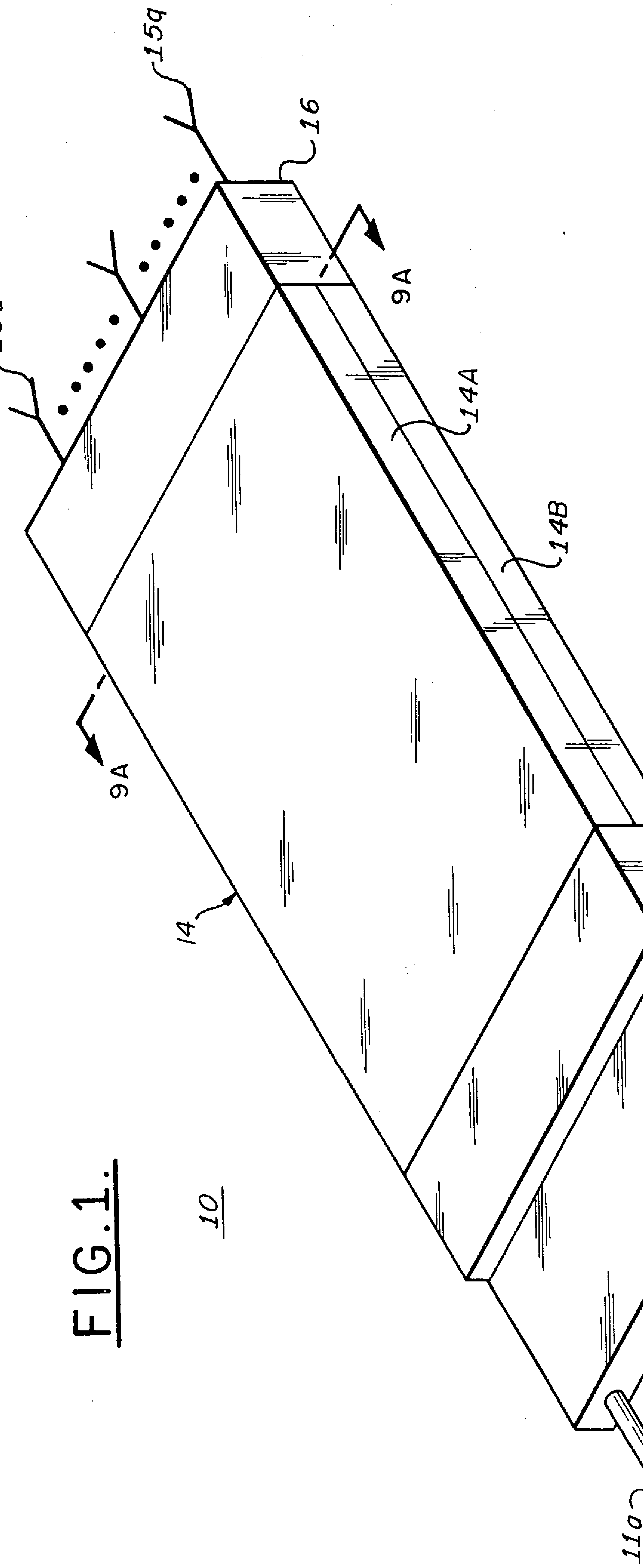

15a
15q
16
9A
14A
14B
9A
14
12
11
11n
11a
10

FIG. 1.

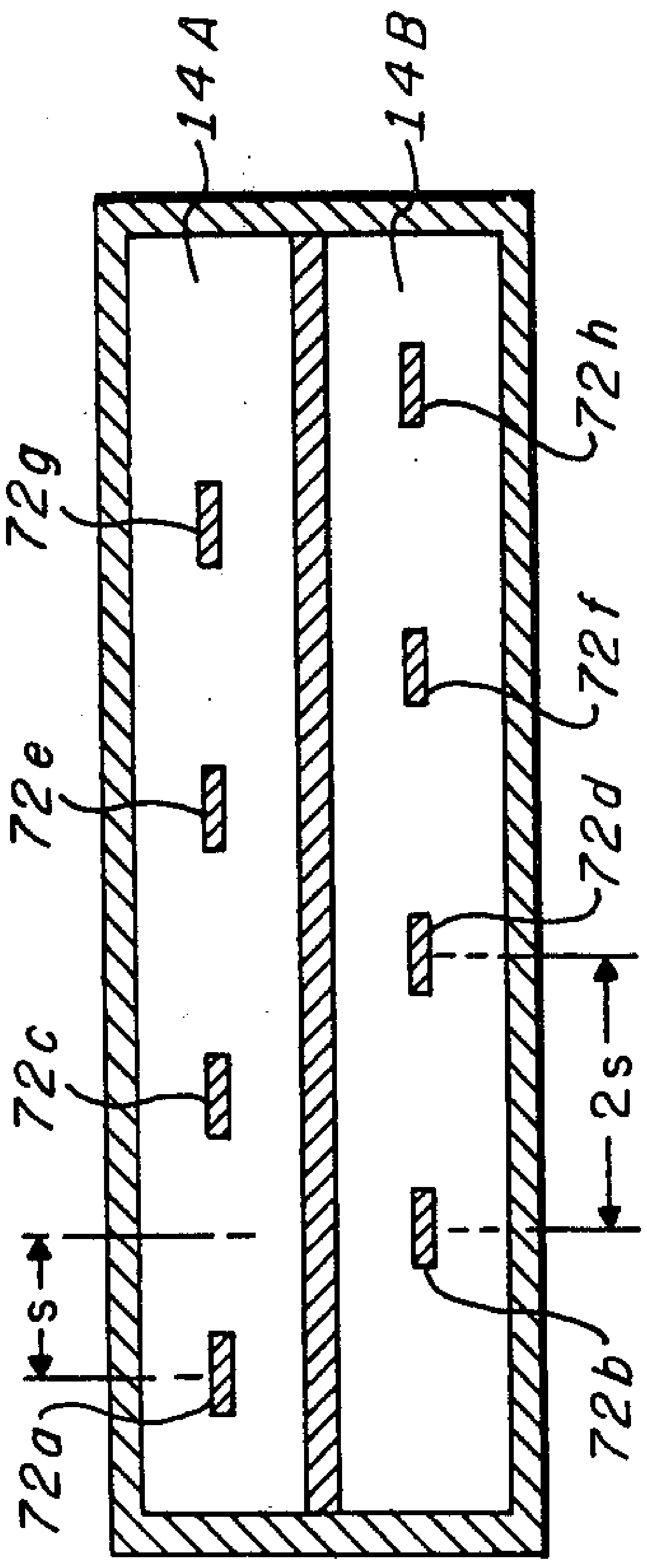
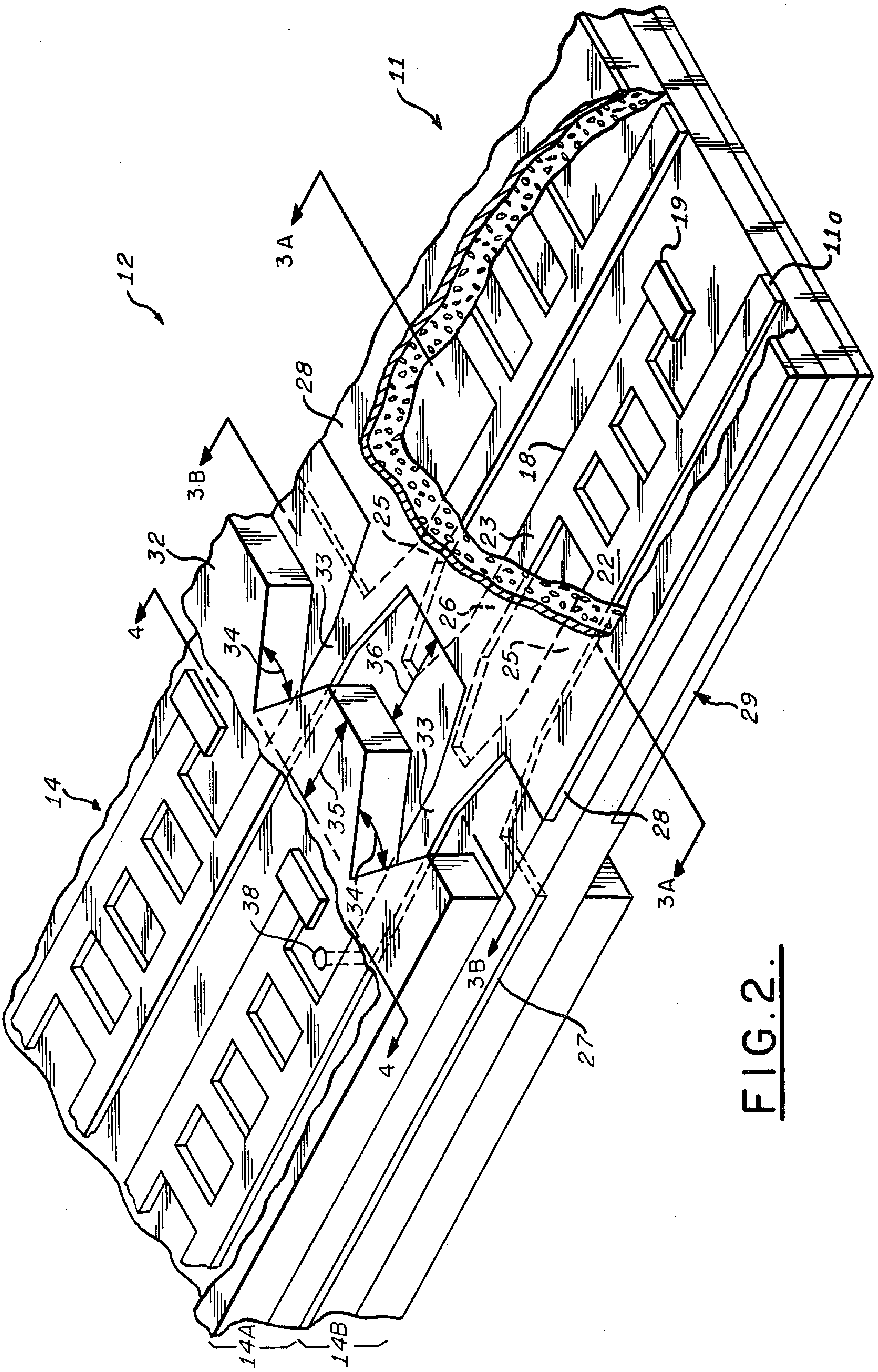

14A
14B
72g
72h
72e
72f
72c
72d
s
2s
72a
72b

FIG. 9A.


11
12
3A
28
3B
32
4
34
33
25
26
23
22
18
19
11a
36
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33
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29
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3A
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38
3B
27
4
14
14A
14B

FIG. 2.

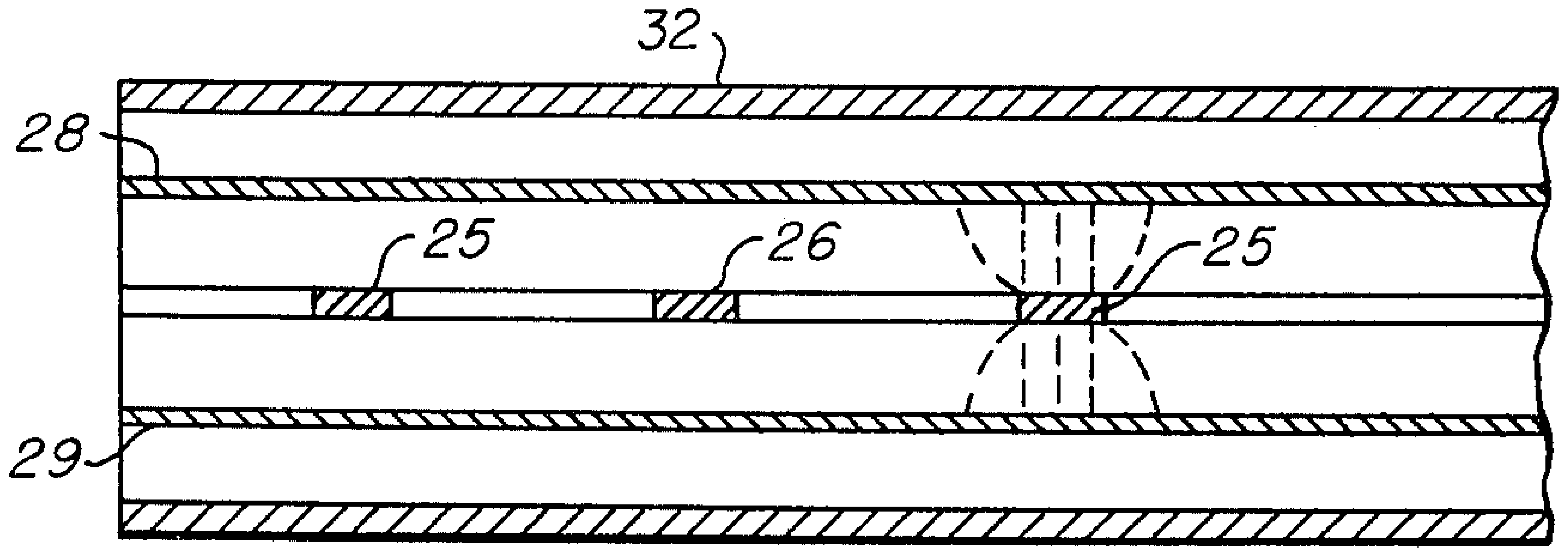

FIG.3A.

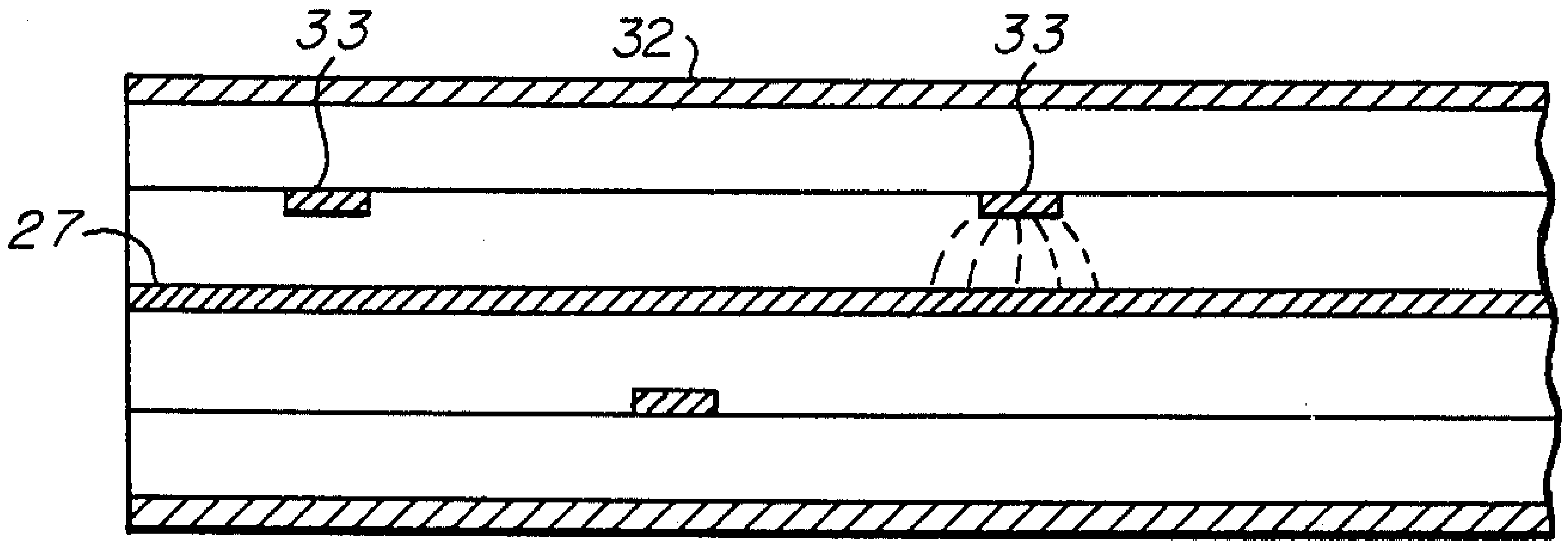

FIG.3B.

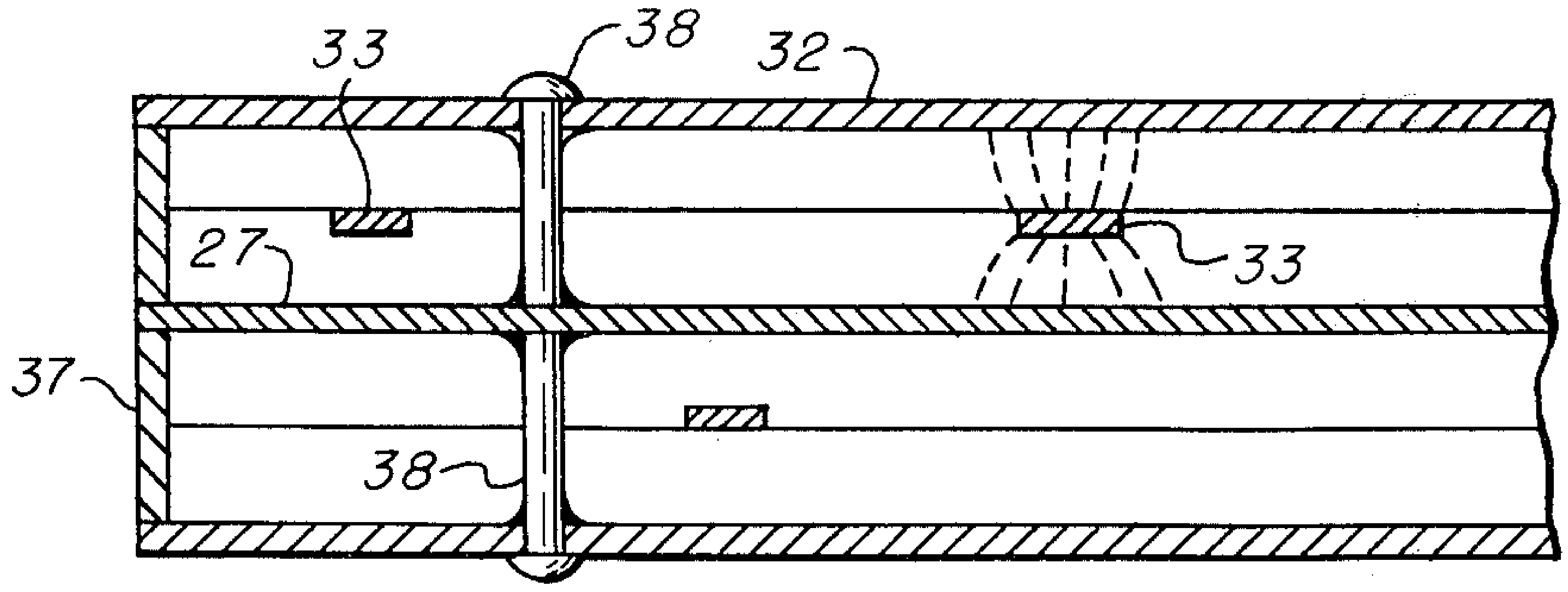

FIG.4.

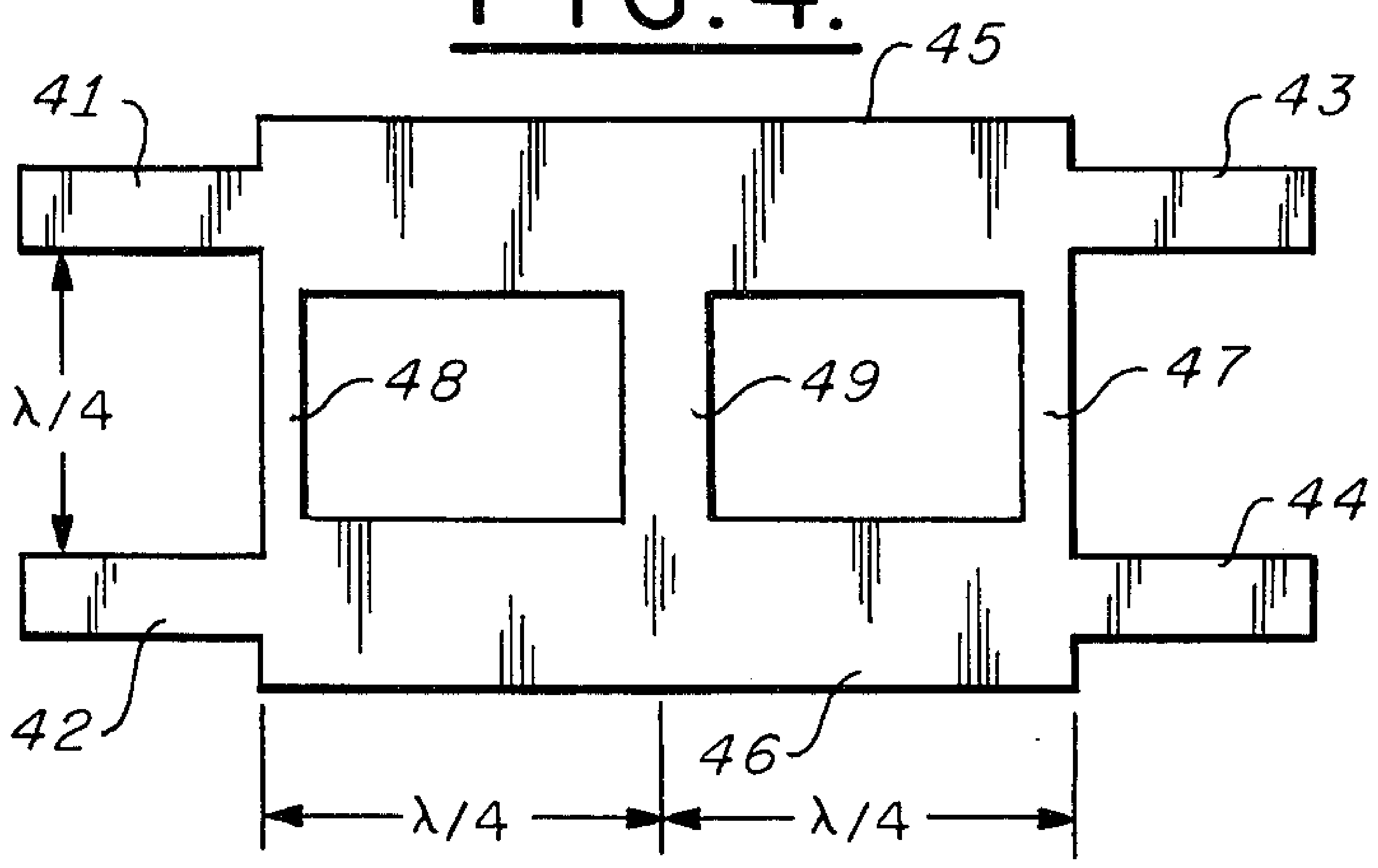

FIG.5.

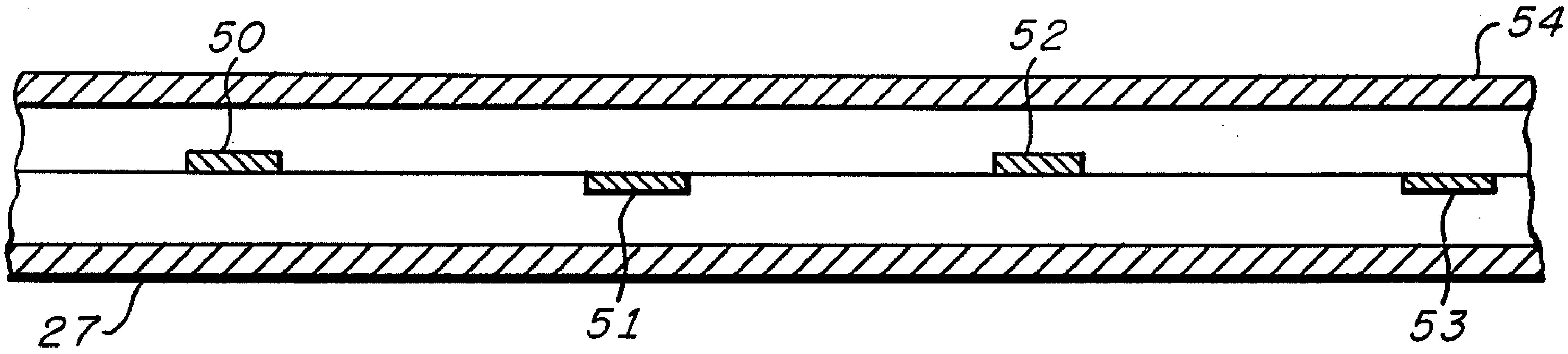

FIG. 6.

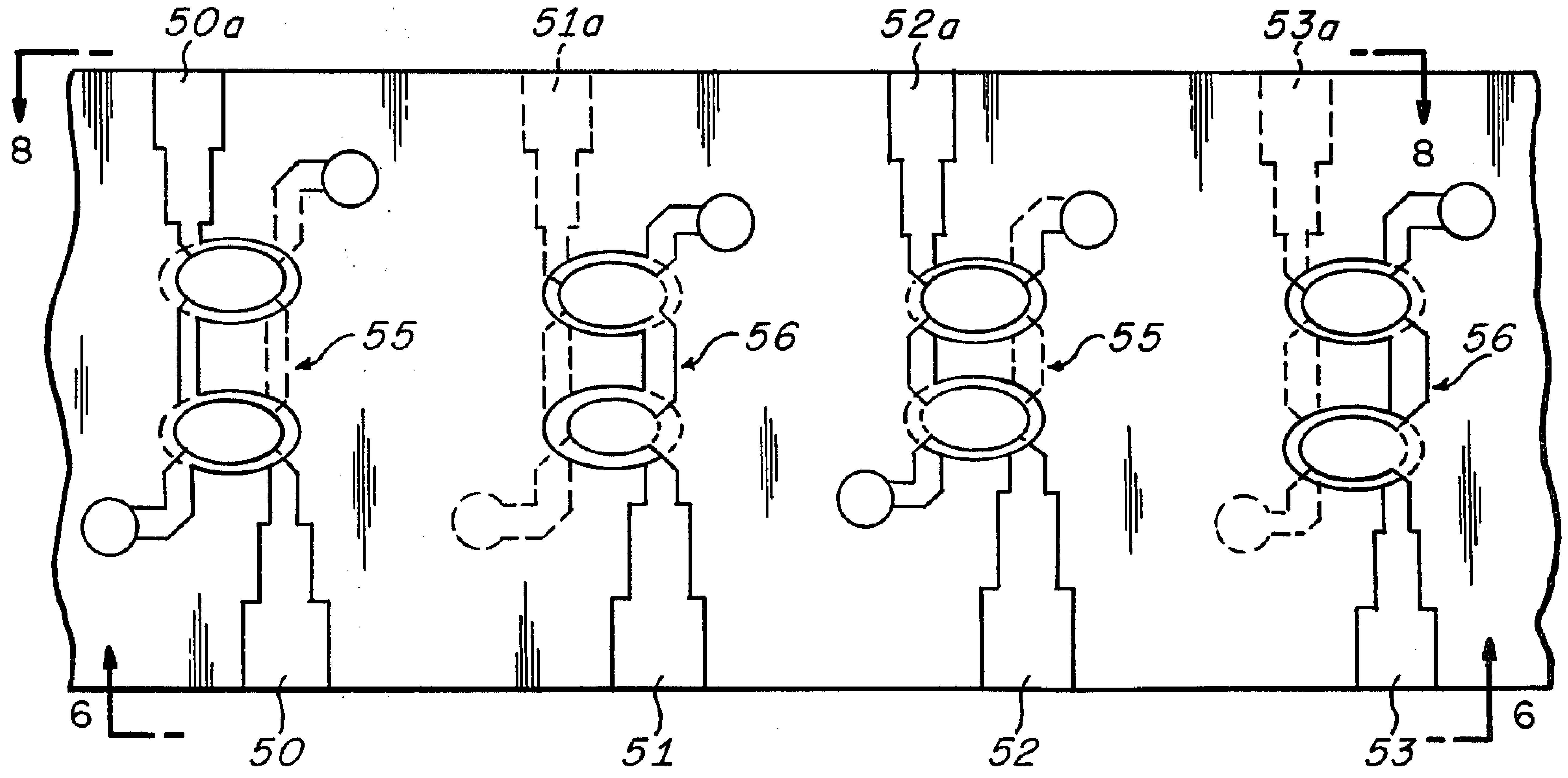

FIG. 7.

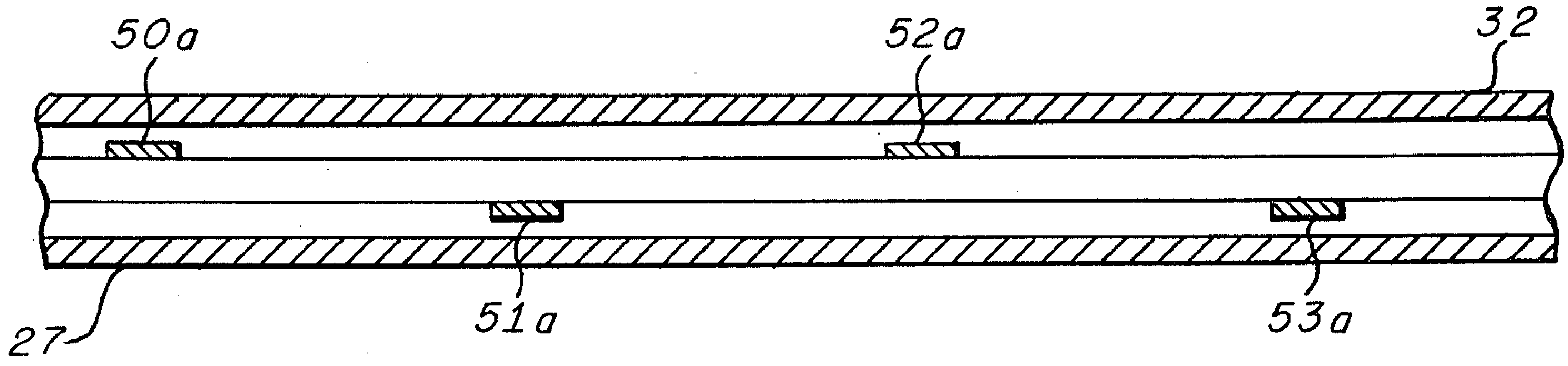

FIG. 8.

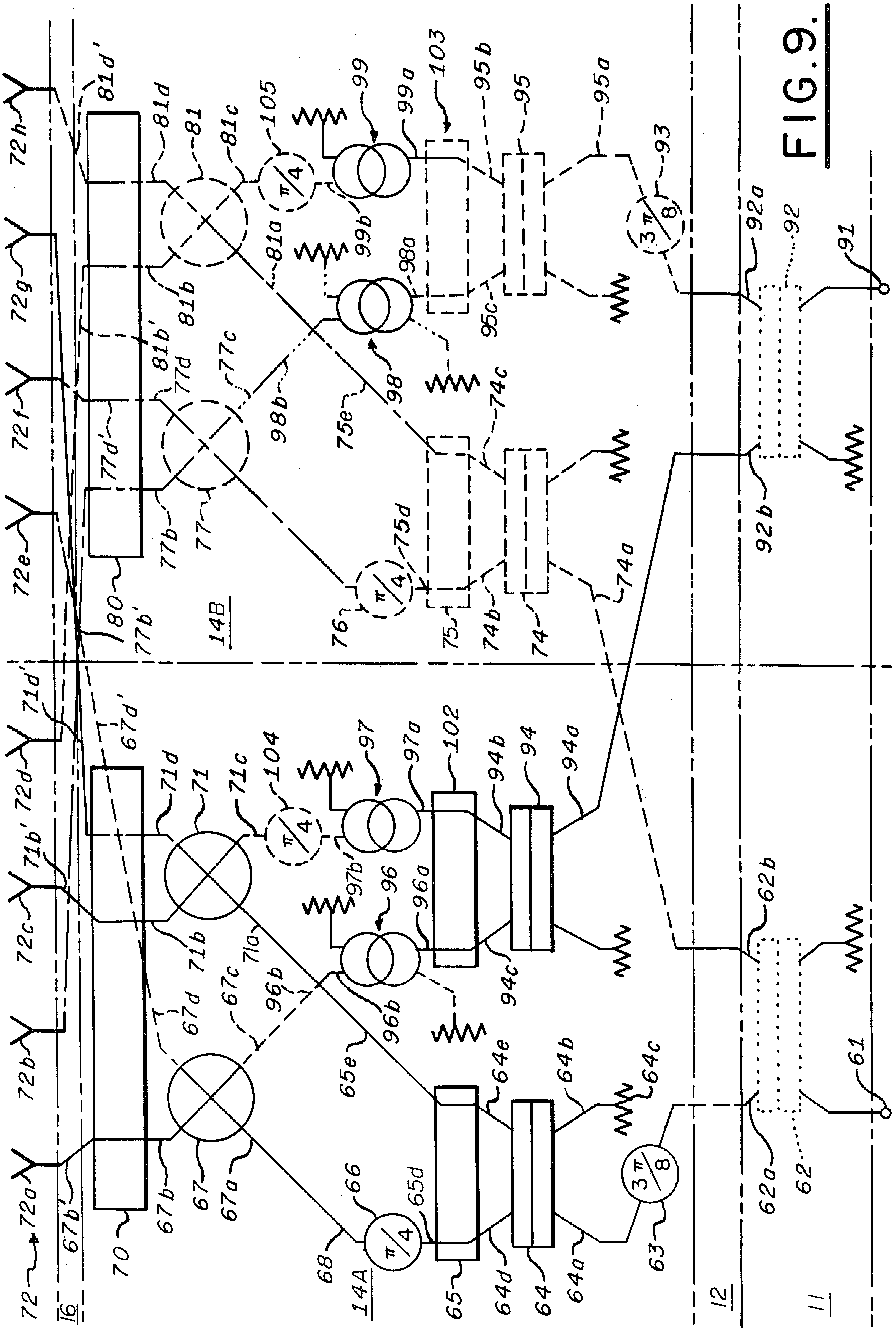
72
72a
72b
72c
72d
72e
72f
72g
72h
71b'
71d'
16
67b
67b'
70
67
67a
67c
67d
67d'
71
71a
71b
71c
71d
104
96
96a
96b
97
97a
97b
102
94
94a
94b
94c
14A
68
66
65
65d
65e
64
64a
64b
64c
64d
64e
63
3π/8
π/4
62
62a
62b
61
12
11
14B
80
77b'
77
77b
77c
77d
77d'
81
81a
81b
81b'
81c
81d
81d'
105
99
99a
99b
98
98a
98b
103
95
95a
95b
95c
93
92
92a
92b
91
76
75
75d
75e
74
74a
74b
74c

FIG. 9.

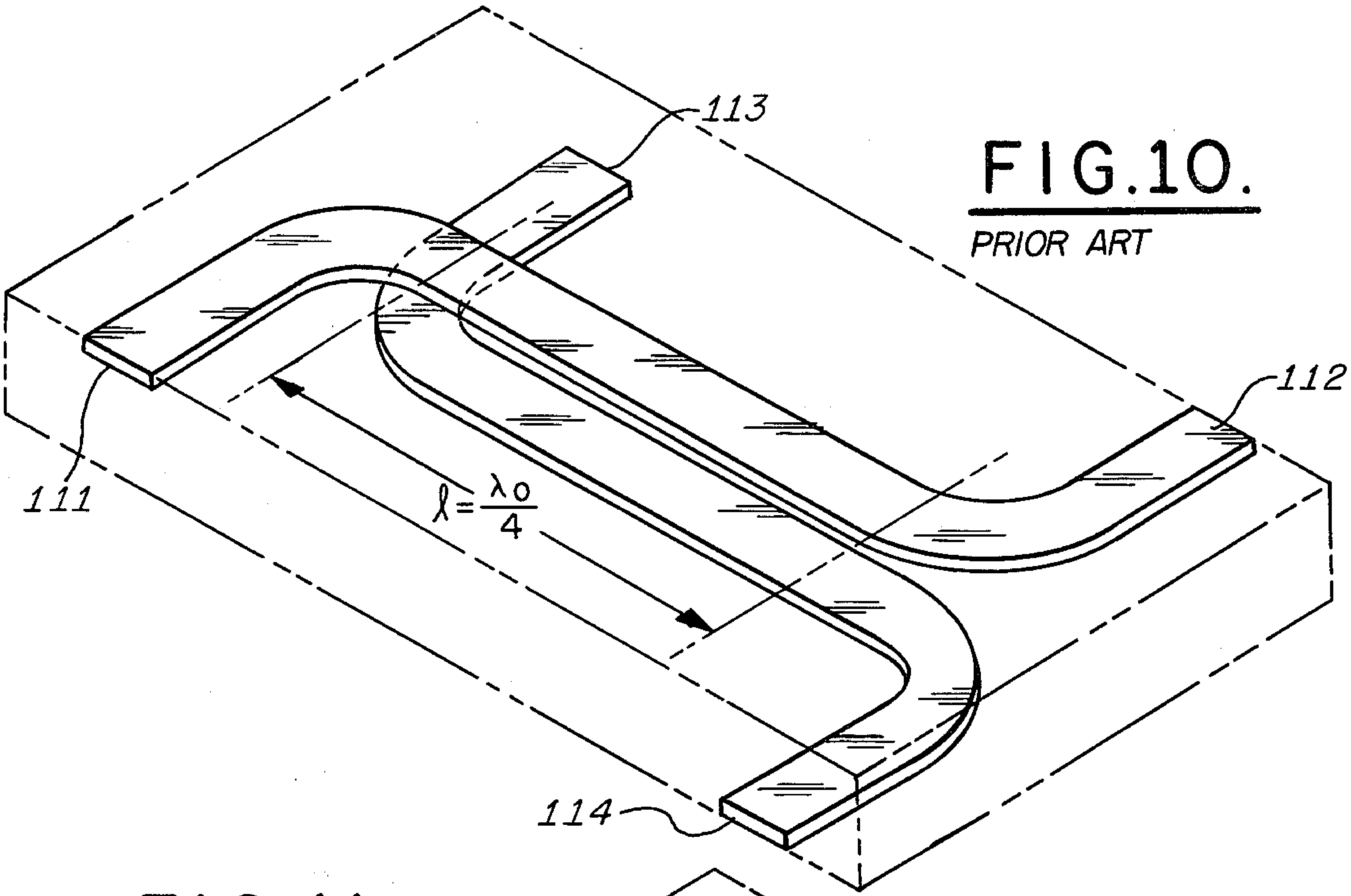

FIG. 10.
PRIOR ART

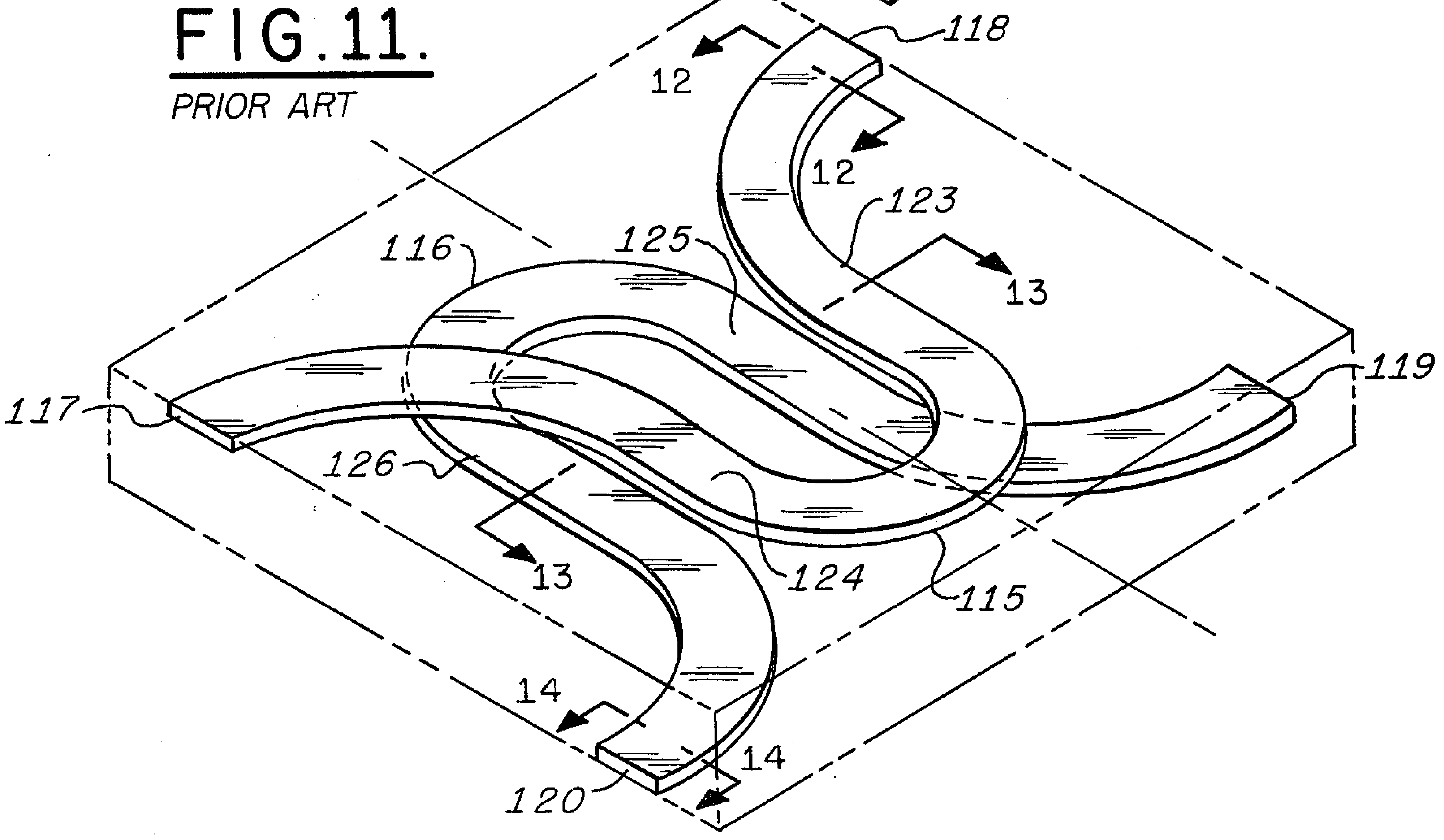

FIG. 11.
PRIOR ART

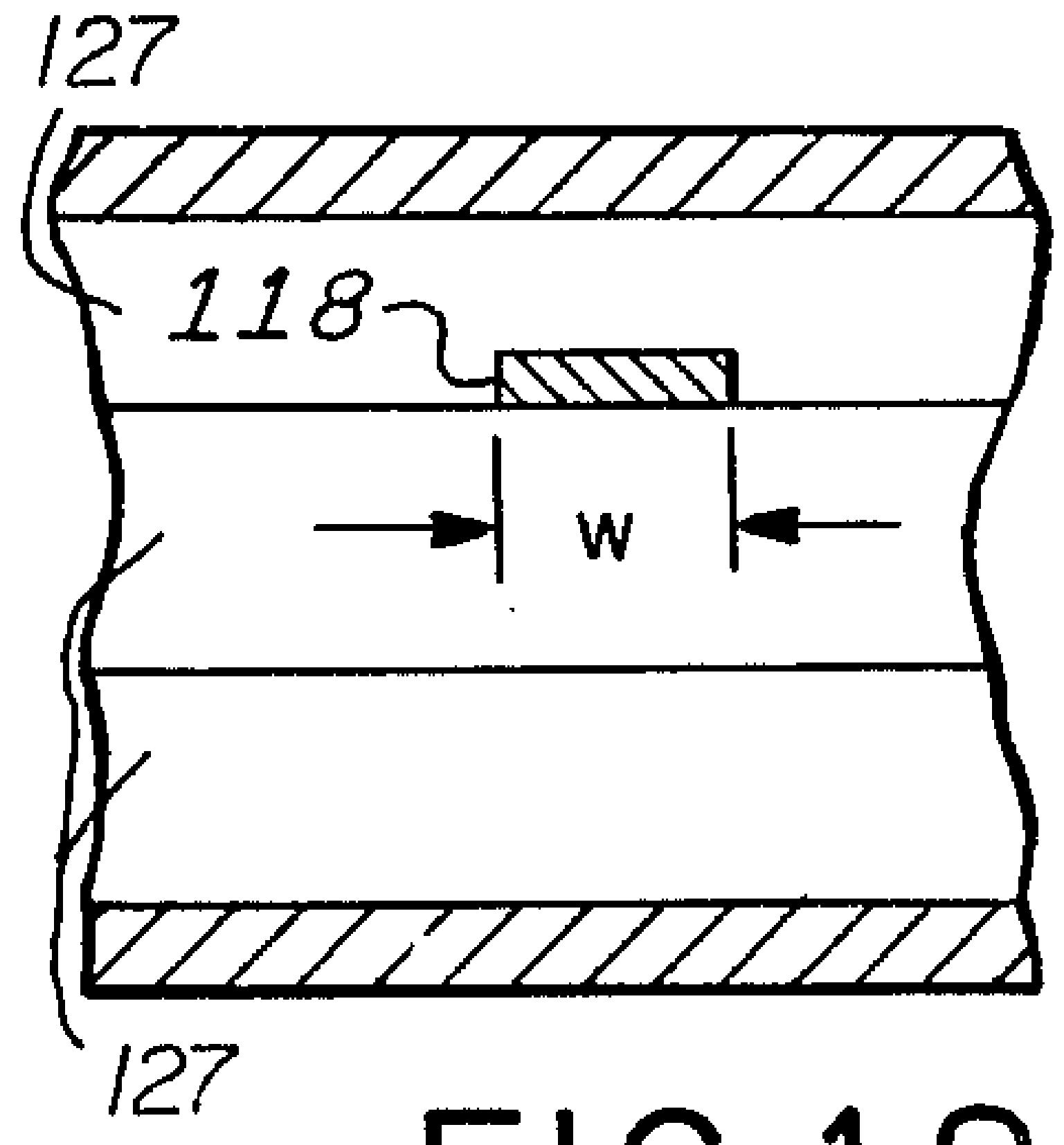

FIG. 12.

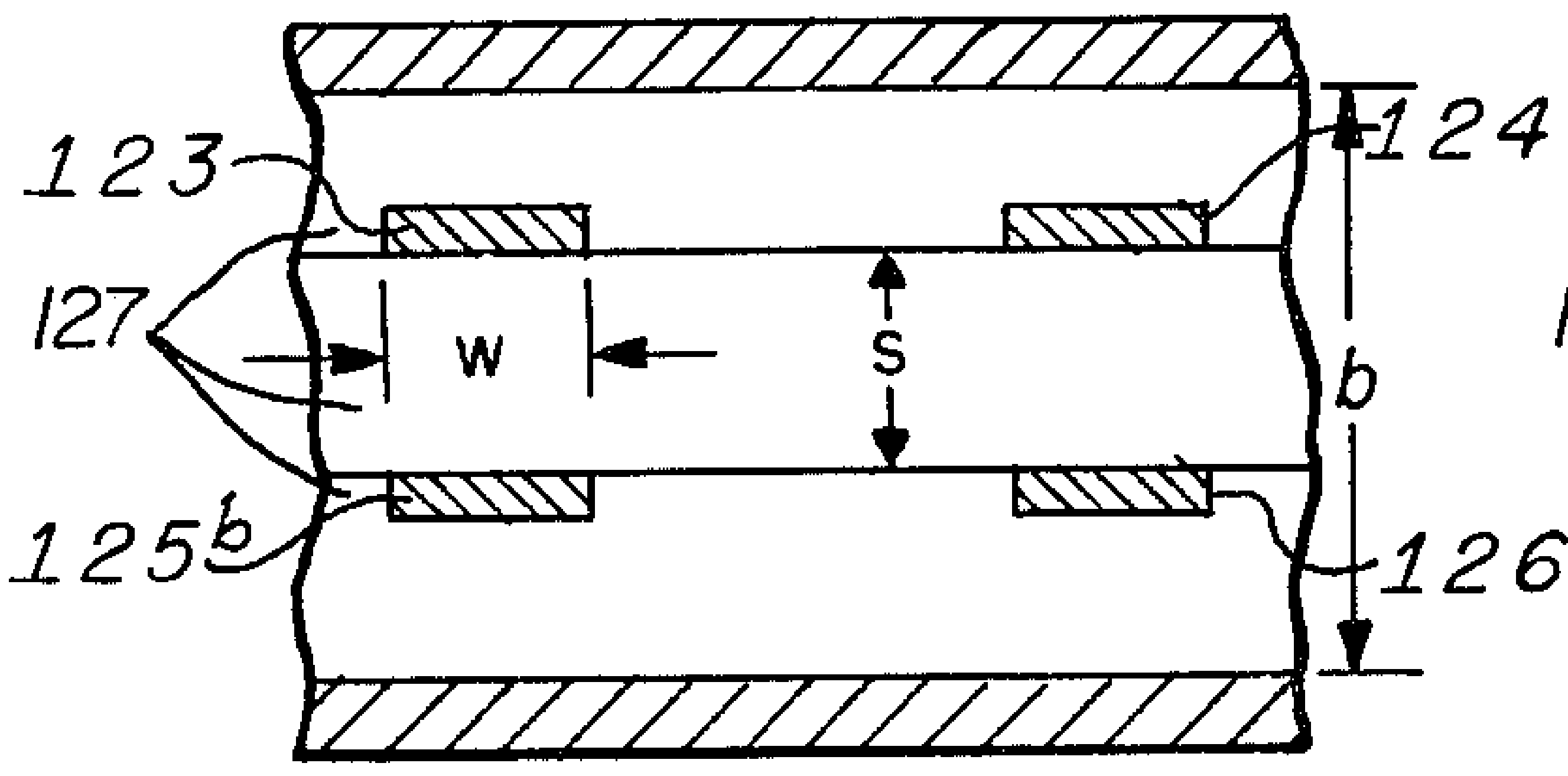

FIG. 13.

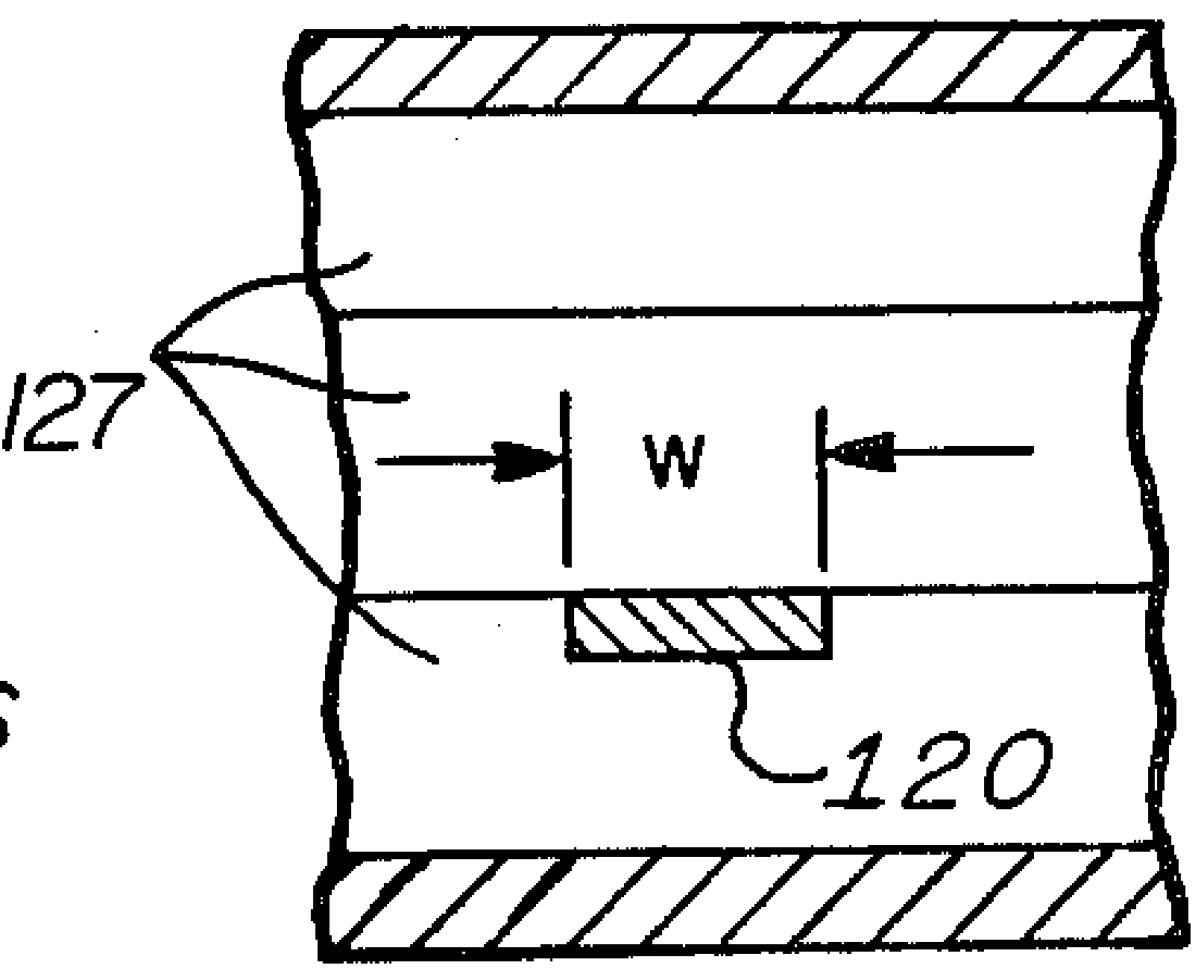

FIG. 14.

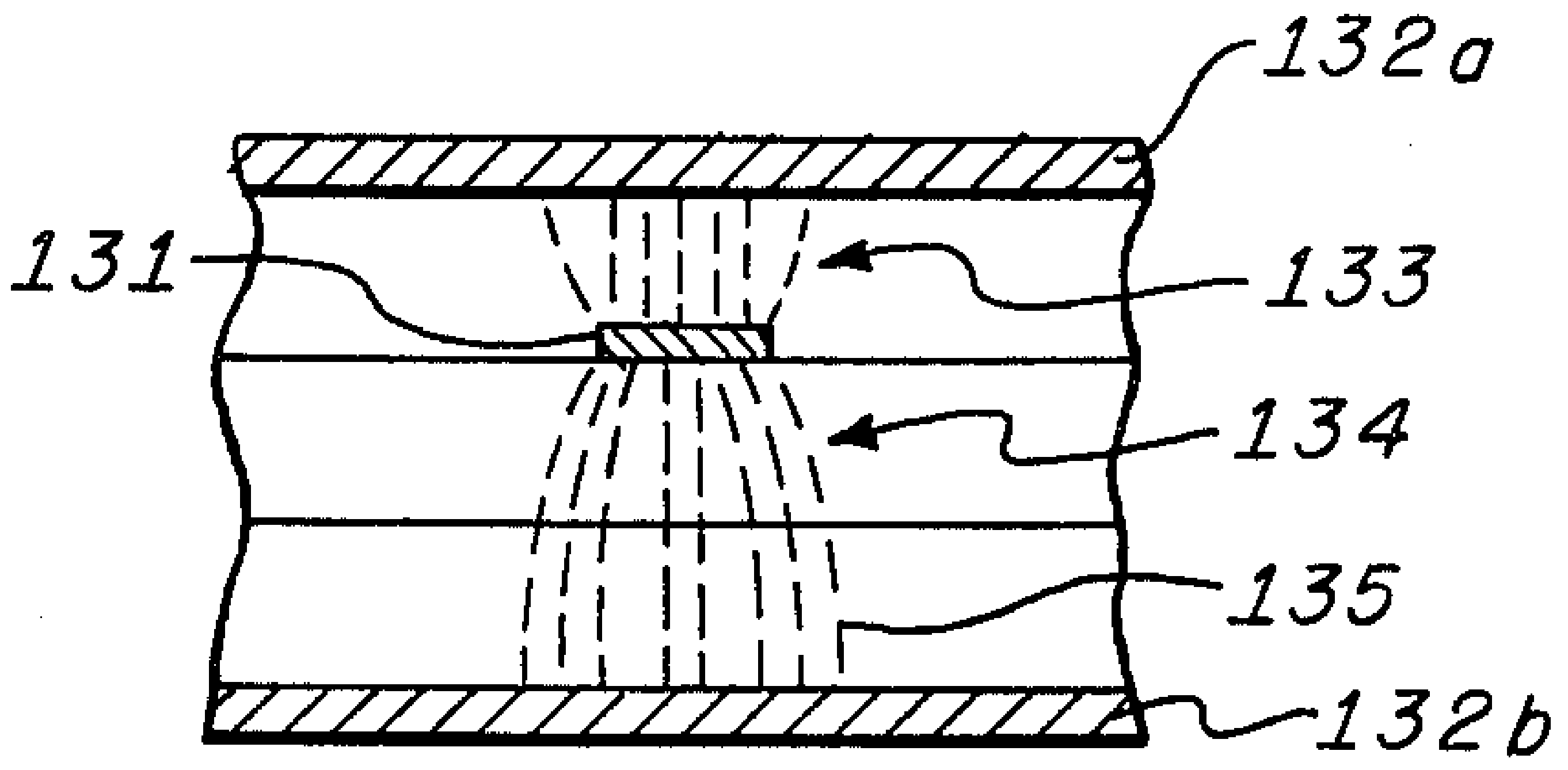

FIG. 15.

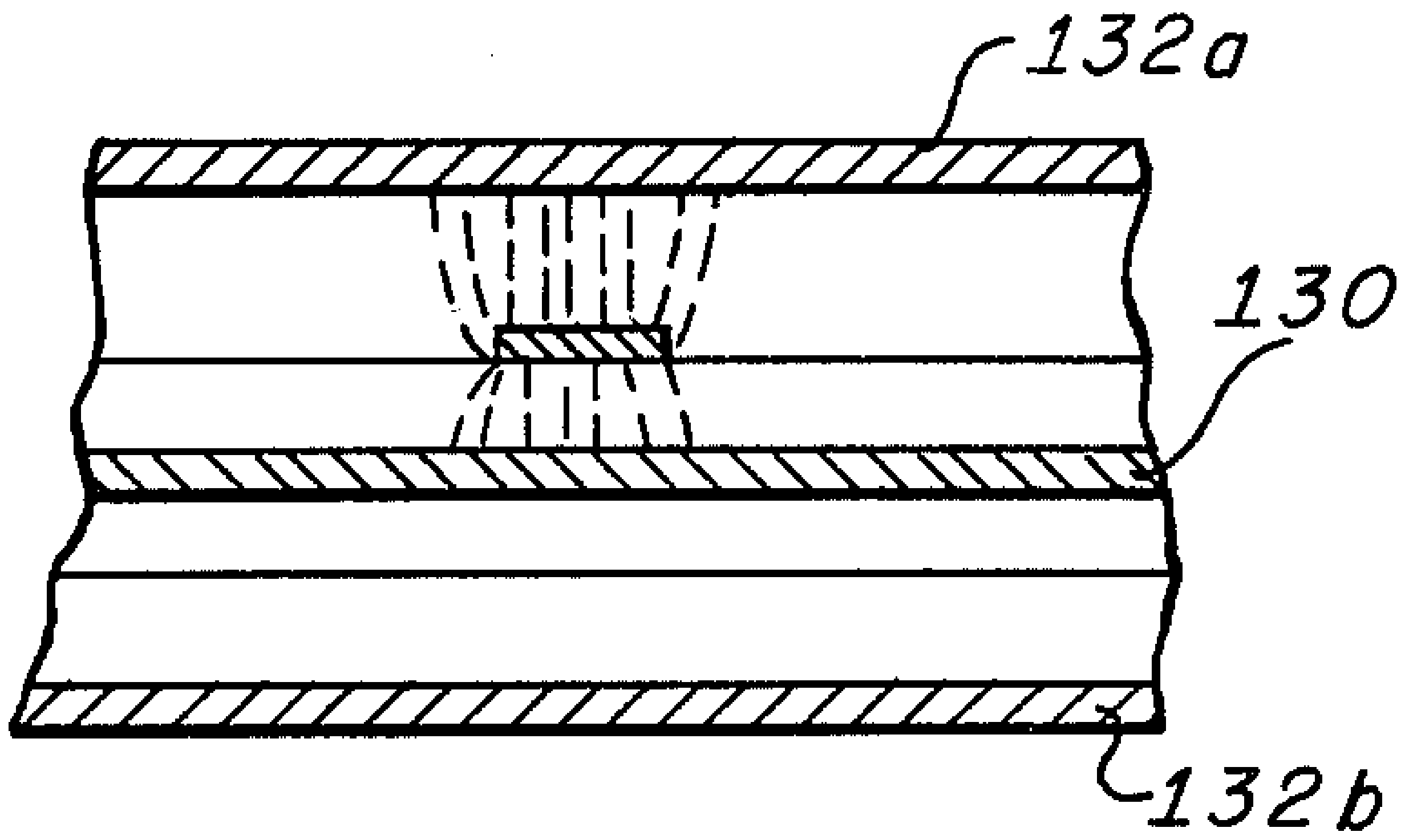

FIG. 16.

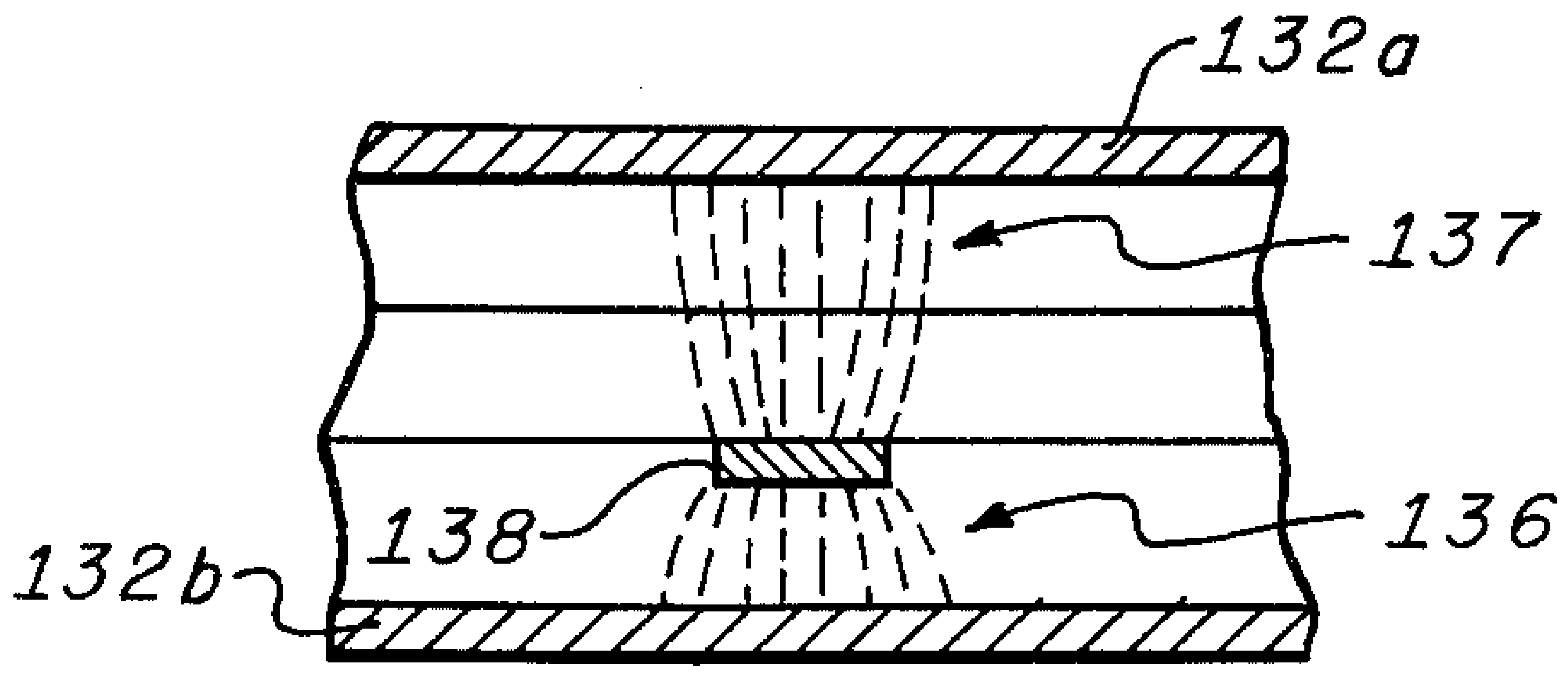

FIG. 17.

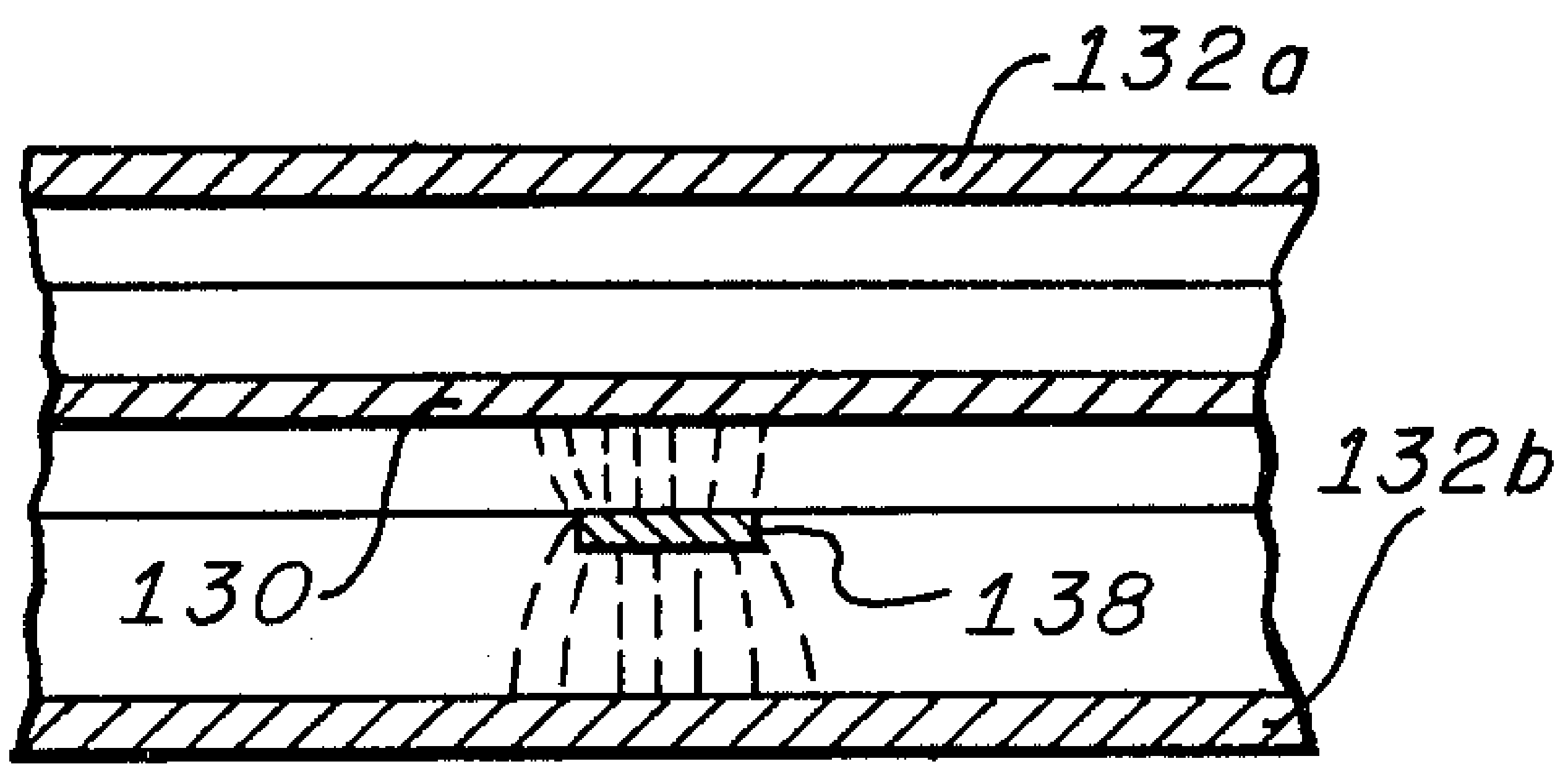

FIG. 18.

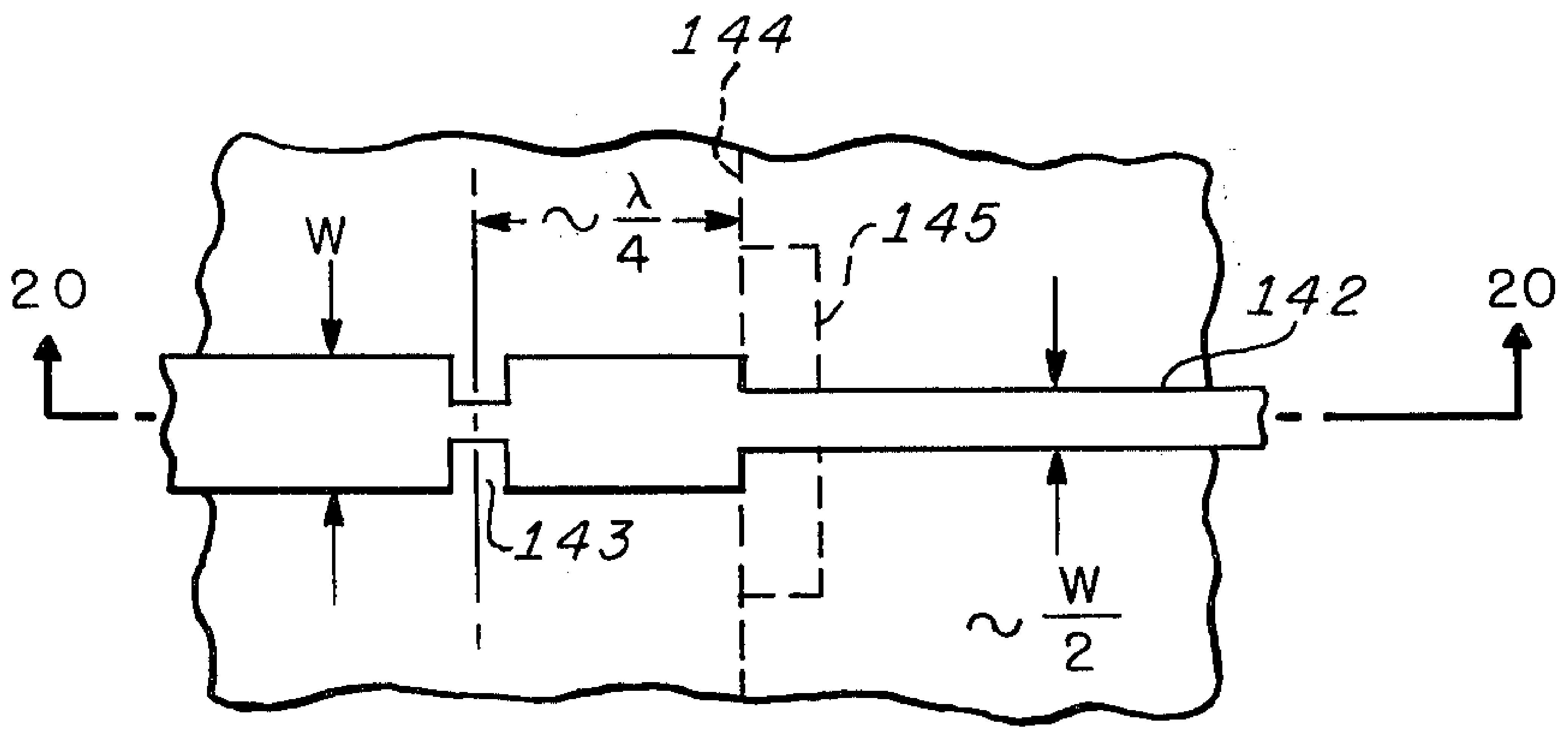

FIG. 19.

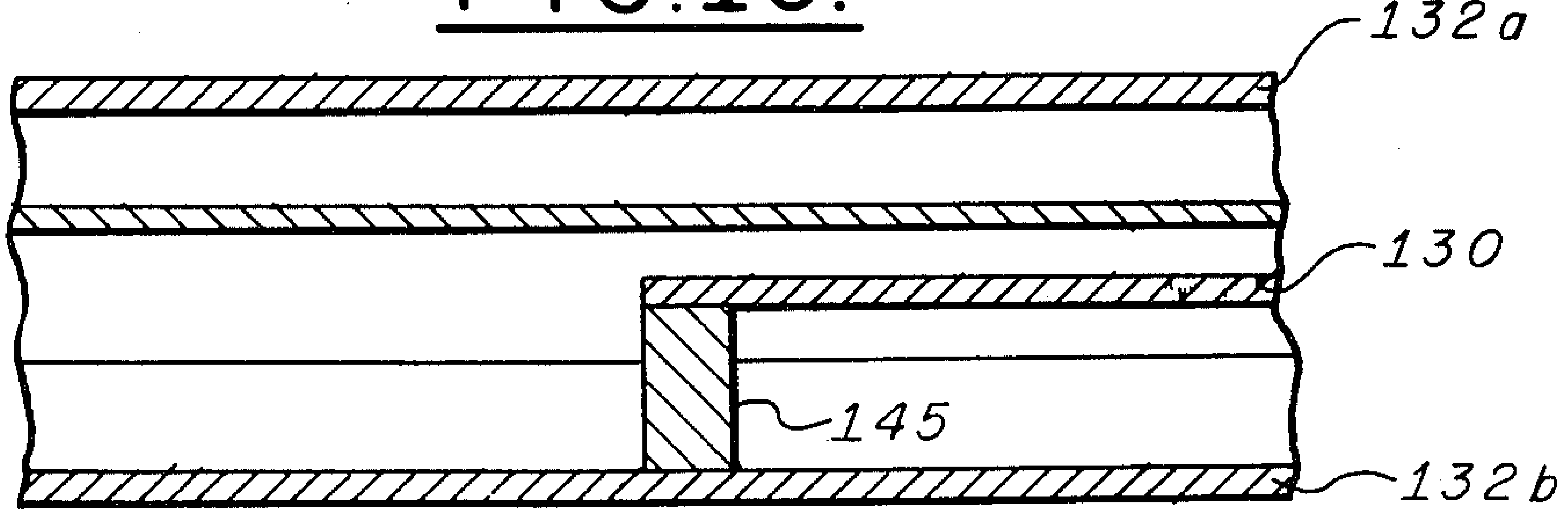

FIG. 20.

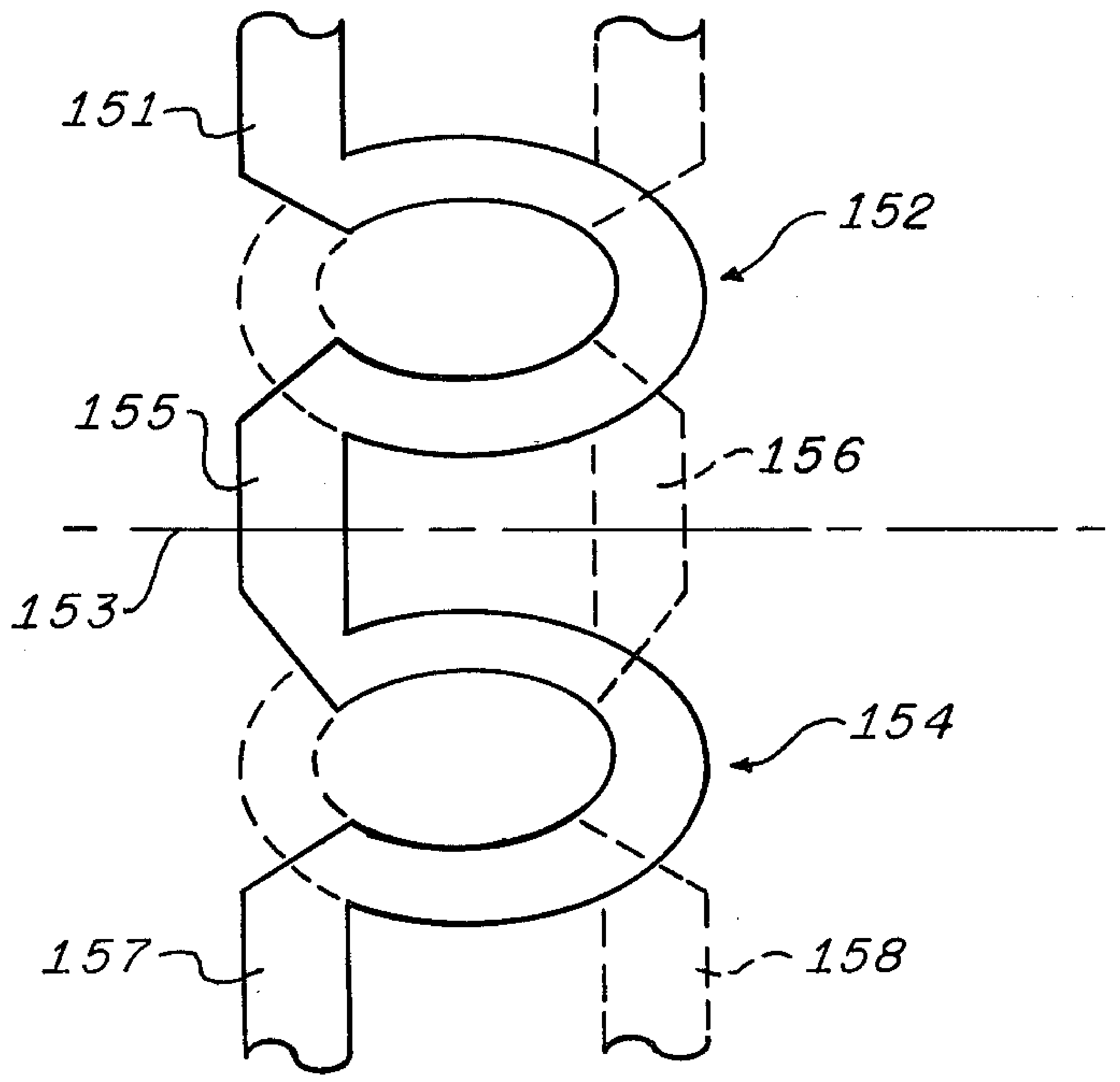

FIG. 21.

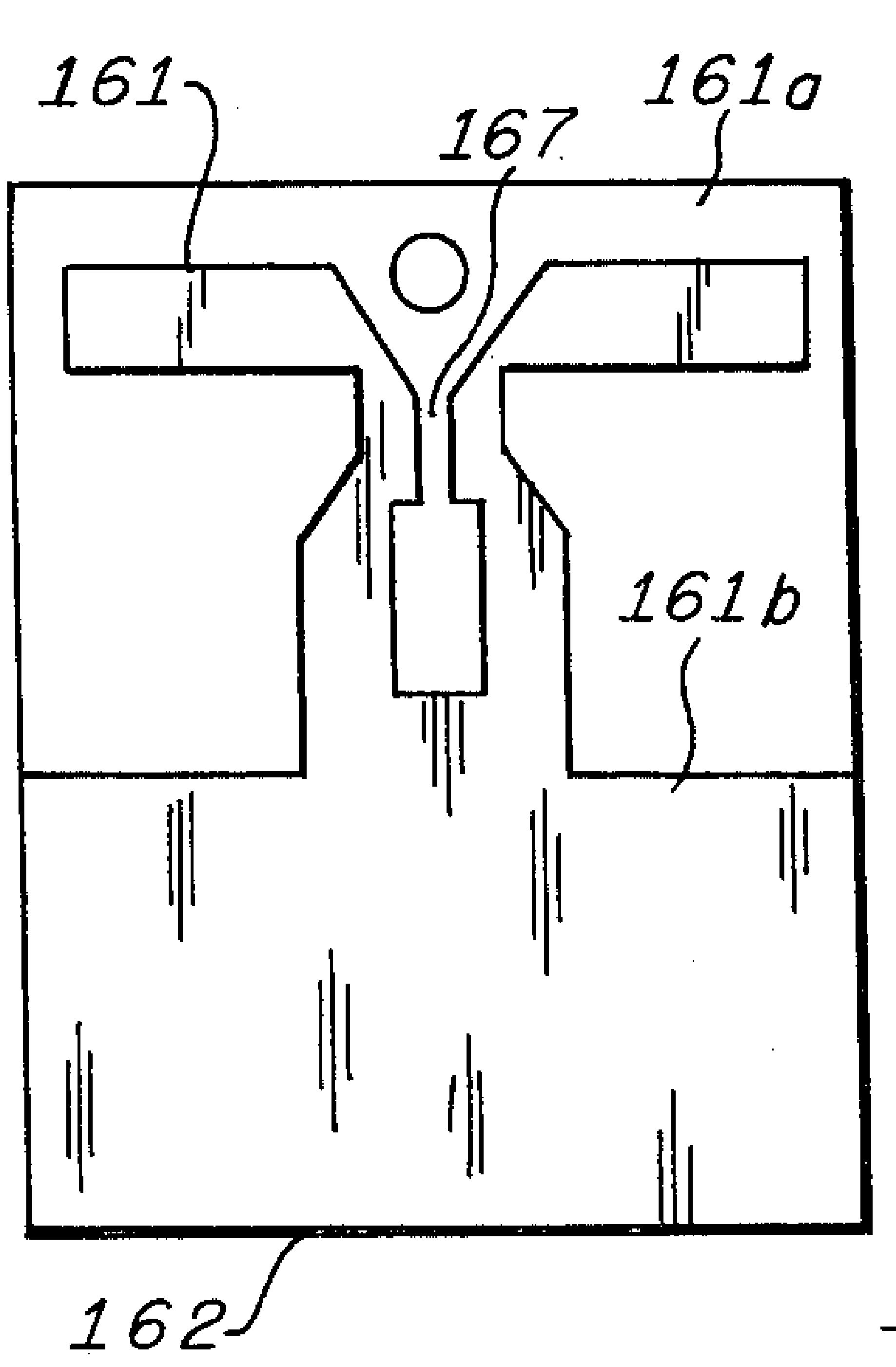

FIG. 22.

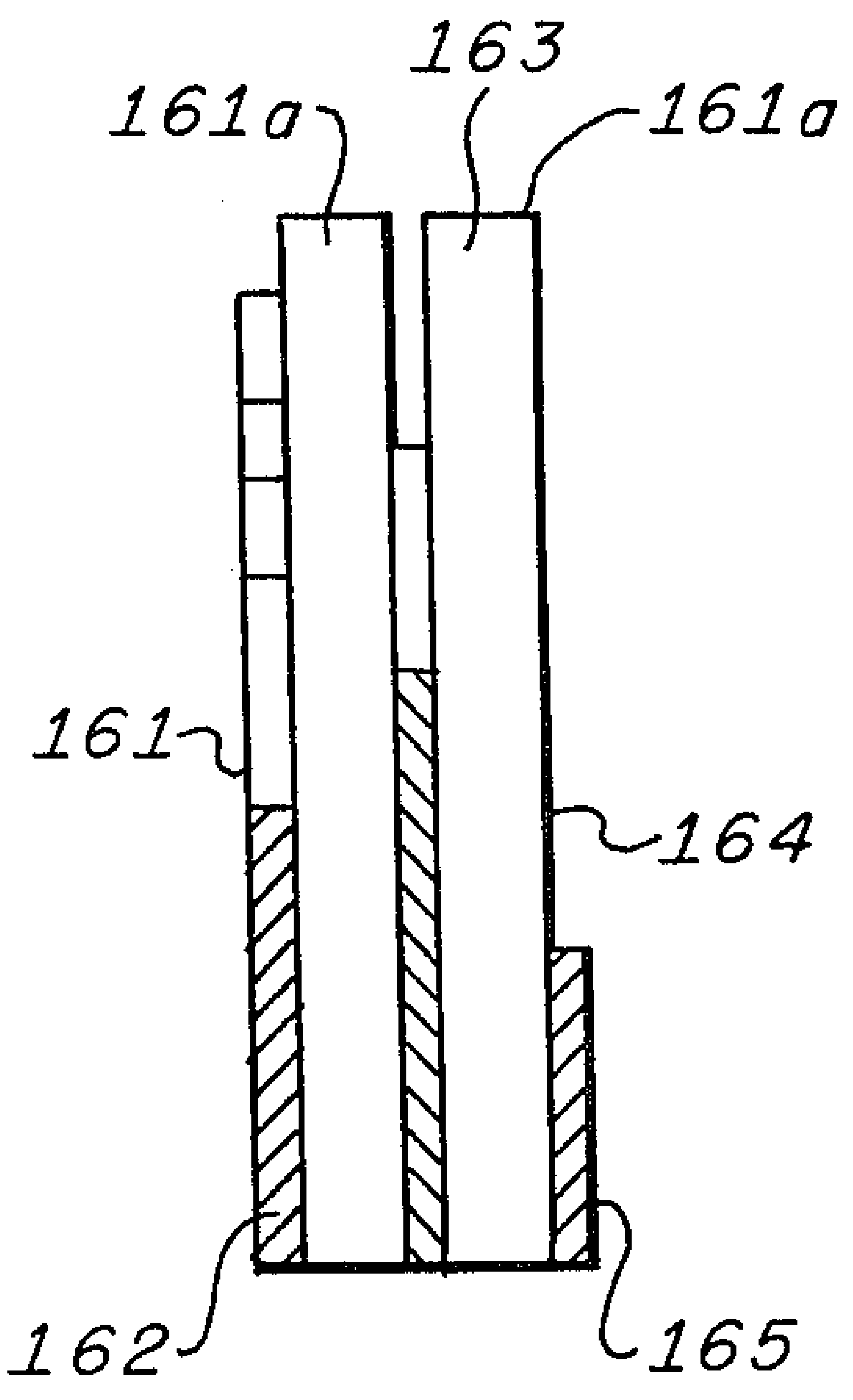

FIG. 23.

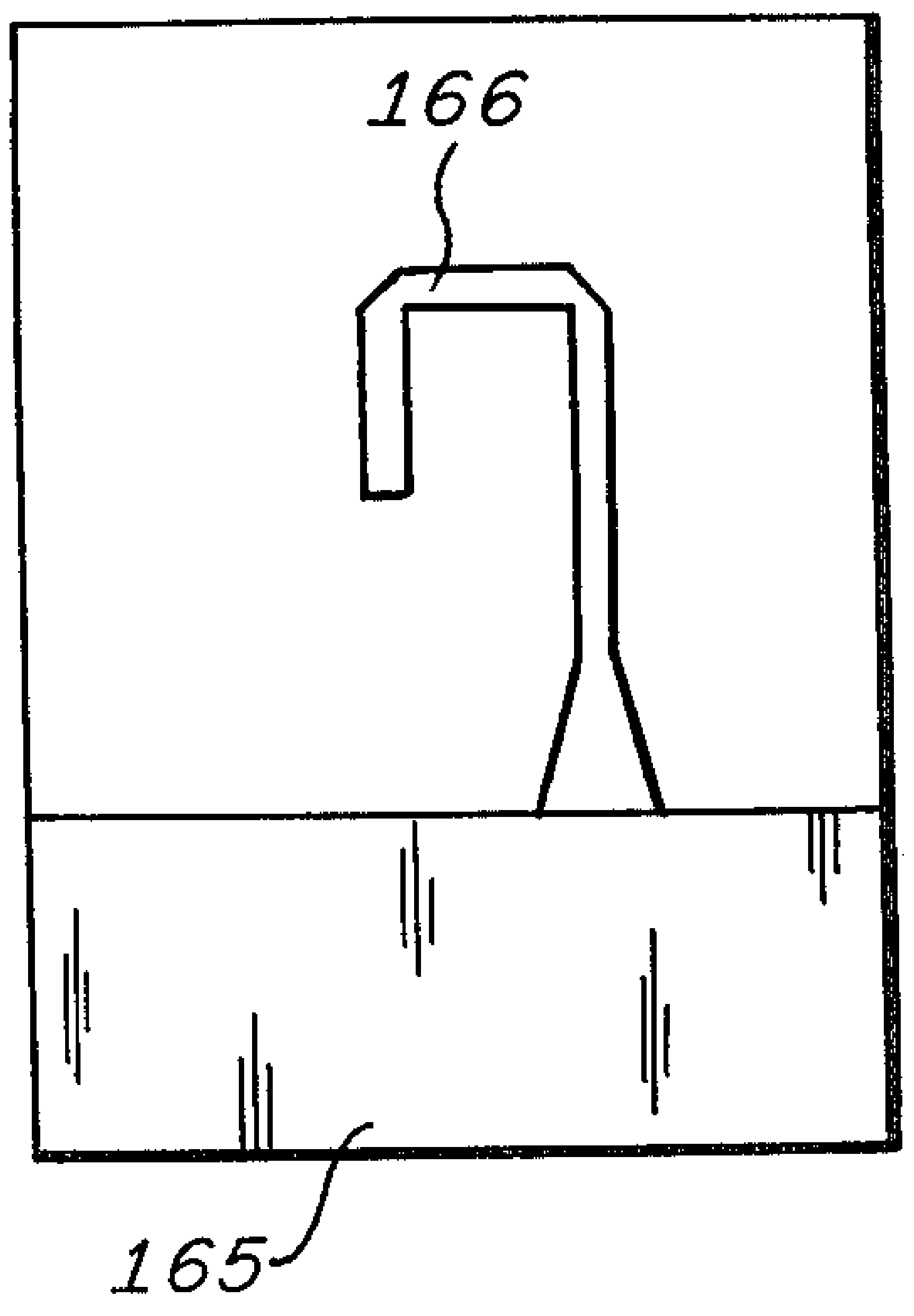

FIG. 24.

BEAM FORMING NETWORK FOR A MULTIBEAM ANTENNA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to feed networks for array antennas and more particularly to beam forming networks to feed array antennas in a manner to establish multiple independent radiated beams.

2. Description of the Prior Art

An array of antenna elements may provide simultaneous multiple beams with the utilizaton of a beam forming network that couples each input port of a multiplicity of input ports to all the elements in the atennan array. A signal at an input port is coupled through the network to all the array elements to establish an aperture distribution to radiate a beam in a direction associated with that input port. One such beam forming network, generally known as a Butler matrix, performs this coupling losslessly with a minimum number of directional couplers and fixed phase shifters. This network, however, requires a large number of transmission line crossovers within the network in order to establish the proper aperture distribution for each beam in space. When stripline is utilized in the transmission line for the network, these crossovers are accomplished with multideck stripline circuits and interdeck connections. These interdeck connections are generally accomplished by positioning connecting metal pins between the decks on which the striplines to be connected are located and soldering the striplines to these interdeck connecting pins. For many applications this type of construction establishes amplitude and phase distributions across the aperture within tolerance limits that provide acceptable free space antenna patterns. In applications, however, wherein low antenna side lobe levels are required, the random phase shifts and junction losses realized through the multiplicity of interdeck connections make it difficult to maintain the necessary aperture phase and amplitude distribution tolerance limits. Though low antenna side lobes may be realized with this type of construction, their achievement is difficult and costly.

SUMMARY OF THE INVENTION

A beam forming network for a multi-beam antenna constructed in accordance with the principles of the present invention includes a power divider for coupling each of n co-planar input ports through at least two nonplanar output ports which in turn are coupled to corresponding input ports of a multi-decked beam forming matrix. Each deck of the beam forming matrix is multi-levelled and is constructed with stripline circuitry to form a Butler matrix. Line crossovers inherent to the Butler construction are accomplished with circuit elements that couple signals between levels of a deck so that crossing lines are located at different levels. These elements eliminate the necessity for utilizing pin level transitions to avoid the intersection of crossing lines at equal levels. The output terminals of the Butler matrix, which are at two different levels for a two deck Butler matrix construction, are coupled to an element level transformer which provides a transition from this multilevel array of terminals to an array of co-planar antenna elements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a representation, partially in isometric view, of the assembled major components of an antenna system which utilizes the principles of the present invention.

FIG. **2** is an illustration of the deck level transformer referenced in FIG. **1**.

FIGS. **3A**, **3B** and **4** are cross-sectional views taken through selected sections of the deck level transformer of FIG. **2**.

FIG. **5** is a plan view illustrating a 3 dB coupler useful in the apparatus of FIG. **1**.

FIGS. **6** through **8** are plan and elevation views of an interlevel transformer useful in the apparatus of FIG. **1**.

FIG. **9** is a schematic diagram of a two beam eight element array utilizing the principles of the present invention.

FIG. **9A** is a cross-sectional view of FIG. **1** looking towards the Butler matrix at its junction with the Element Level Transformer.

FIG. **10** is a perspective view of the inner conductors of an interlevel directional coupler.

FIG. **11** is a perspective view of the inner conductors of a 3 dB interlevel coupler.

FIGS. **12** through **14** are cross-sectional views of selected sections of FIG. **11**.

FIGS. **15**–**18** are cross-sectional views depicting transitions from full height asymmetrical striplines to half height asymmetrical striplines with electrical field lines between the inner conductor and ground indicated thereon.

FIG. **19** is a plan view of a matching network useful for matching a full size asymmetric stripline to a half size asymmetric stripline.

FIG. **20** is a cross-sectional view of the matching network of FIG. **19**.

FIG. **21** shows interlevel couplers.

FIGS. **22** through **24** are top, side and bottom views of the Element Level Transformer referenced in FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a multibeam antenna system **10** incorporating the principles of the present invention includes a power divider **11** which couples signals incident to each of the input terminals **11***a* through **11***n* to at least two input terminals of a deck level transformer **12**, such as that described in our corresponding U.S. patent application Ser. No. 220,226. Each of the input terminals of deck level transformer **12** is coupled to a designated inner conductor of a symmetrical stripline system on a preselected deck of at least two decks of stripline circuitry forming Butler matrix **14**. The inner conductors of each of the at least two decks of stripline circuitry are converted to asymmetrical striplines by means of symmetric-asymmetric stripline transformers contained in decks **14A** and **14B** of Butler matrix **14**, wherefrom they are coupled to the circuitry on designated levels comprising the Butler matrix **14**. The outputs ports of each deck of the Butler matrix are in symmetric stripline and are uniformly distributed in the central planes of each deck. These output ports are transformed to a common level and appropriately coupled to co-planar antenna elements **15***a* through **15***q* by element level transformer **16**.

Coupling each input port **11***a* through **11***n* to the two decks of the Butler matrix **14**A and **14**B of the Butler matrix **14** may be accomplished through the power divider **11**, yet to be described, and the deck level coupler **12** shown in FIG. **2**. An input port, as for example port **11***a*, is coupled to one arm of a three branch 3 dB stripline coupler **18**, the adjacent arm of which is coupled to a matched termination **19** while the output ports **22** and **23** are coupled to the input striplines **25** and **26** of the deck level coupler **12**. Deck level coupler **12** may be constructed by transforming the input striplines **25** and **26** to the common ground plane **27** of the decks **14**A and **14**B and converting the upper **28** and lower **29** ground planes at the input end of the deck level coupler **12** to the center conductors of the upper deck **14**A and lower deck **14**B respectively.

Commencing with the multi-deck section of the deck level coupler **12**, the upper ground plane **32** is gradually removed in the vicinity of the stripline conductors **33** with a taper angle **34** which extends a distance **35** from the apex after which the ground plane is completely removed establishing a microstrip circuit over this distance for the center conductors **33**. The center conductors **33** are broadened using a broadening angle similar to the angle **34** for a distance **36** after which all center conductors **33** merge with the ground plane **28** of the symmetrical stripline section of the deck level coupler **12** which couples to the power divider **11**. Over the distance **36**, the center strips **25** of the symmetrical stripline section are similarly tapered to merge with the common ground plane **27** between the upper deck **14**A and the lower deck **14**B. This transition is shown in cross-section in FIGS. **3**A, **3**B, and FIG. **4**. In a similar manner, the center strips **26** are merged with the common ground plane **27** and the center strips of the lower deck **14**B are converted to the lower ground plane **29** of the symmetrical stripline section of the deck level coupler **12**.

Each of the three branch 3 dB couplers may be designed by methods well known in the art, as for example the method described by Reed and Wheeler in the IRE Transactions on Microwave Theory and Techniques, Volume MTT-4, Number 4, October 1956. A coupler designed with this procedure to match a 50 ohm symmetrical stripline may take the form shown in FIG. **5** wherein the circuit coupling sections **41**,**42**, **43** and **44** are each 50 ohms, the intercoupling sections **45**,**46** and the middle branch **49** are each 35.35 ohms and the branches **47** and **48** are each 120.77 ohms. These impedances provide maximum isolation and minimum coupling variation over a desired band. Over an 11% frequency band the isolation will be greater than 37 dB and the coupling variation will be less than 0.12 dB.

After the transition through the deck level coupler **12**, the stripline in the Butler matrix **14** in each deck **14**A and **14**B will exhibit a symmetric configuration with the central strips substantially equidistant between the upper and lower ground planes as for example the positioning of the central strips **50**,**51**,**52** and **53** of the upper deck **14**A positioned between the lower ground plane coinciding with the common ground plane **27** and the upper ground plane **54** as shown in FIG. **6**. To eliminate costly interlevel pins within the Butler matrix and reduce the number of levels therein to two stripline etched surfaces, this symmetrical stripline is converted to asymmetrical stripline, shown in cross-section in FIG. **8**, by the symmetric-asymmetric line transformer shown in FIG. **7**. In FIG. **7**, 0 dB interlevel couplers **55**, yet to be described, transform the center conductors **50** and **52** to conductors **50***a* and **52***a*, respectively, at the upper level of the asymmetric line while 0 dB interlevel couplers **56** transform the center level conductors **51** and **53** to conductors **51***a* and **53***a*, respectively, at the lower level of the asymmetric line.

The invention will now be more fully described with reference to FIG. **9** which is a schematic diagram of a two beam eight antenna element Butler beam forming network with the elements arranged to be in conformity with the block diagram of FIG. **1**. Though the 2×8 will be described, it will be apparent to those skilled in the art that the principles to be discussed are not limited thereto, and that these principles are applicable to any m×n system.

A signal incident to input port **61** is coupled to a three branch 3 dB coupler **62** of power divider **11** and therethrough to output transmission lines **62***a* and **62***b* with equal amplitude and in-phase quadrature. Throughout this discussion, the convention will be used that the phase shift straight through the directional coupler, such as from input port **61** to output line **62***b*, is 90 degrees while the phase shift in the coupled arm, such as from input port **61** to output transmission line **62***a*, is 0 degrees. Output transmission lines **62***a*, **62***b* are coupled to the deck level transformer **12**, which may be of the type described in U.S. patent application Ser. No. 220,226, and therefrom respectively to decks **14**A and **14**B. Transmission line **62***a* is coupled in deck **14**A through a 67½° phase shifter **63**, which may be of the Schiffman type well known in the art, to an input transmission line **64***a* of a three branch 3 dB coupler **64**, constructed in symmetrical stripline, for which a second input port **64***b* is coupled to a matched termination **64***c*. The output transmission lines **64***d* and **64***e* of the 3 dB coupler **64** are coupled through a symmetric-asymmetric line transformer **65**, yet to be described, to transmission lines **65***d* and **65***e*, respectively, on the upper inner conductor of a two level asymmetric strip transmission line. Transmission line **65***d* is coupled at this level through a 45 degree phase shifter **66** to the input transmission line **67***a* of an interlevel 3 dB coupler **67**, yet to be described, via transmission line **68**. As will be apparent, the inner conductors of transmission lines **65***d* and **65***e* traverse regions wherein crossings by inner conductors on the lower level occur. To provide substantially complete decoupling between the transmission lines associated with the crossing inner conductors, a conversion from full height asymmetric stripline to half height asymmetric stripline is accomplished in the region **69**. This conversion will be explained subsequently with the aid of FIGS. **15** through **20**.

Interlevel 3 dB coupler **67** is a four port device, in full height asymmetric stripline, having an input transmission line **67***a* and an output transmission line **67***b* at a common level, as for example, the upper level of a two inner level asymmetric transmission line and an input transmission line **67***c* and an output transmission line **67***d* at a different level, as for example, the lower level of a two level asymmetric stripline. The coupling between an input transmission line and the two output transmission lines is 3 dB with the signal in the common level output transmission line in-phase with the incident signal and the signal in the non-common level output transmission line in quadrature with the input signal. The output transmission lines **67***b* and **67***d* of interlevel coupler **67** are coupled to asymmetric-symmetric stripline transformer **70** wherein the transmission lines are converted to half height asymmetric stripline and coupled therefrom to a common level.

The output transmission lines **65***e* from the symmetric-asymmetric transformer **65** at the upper level of the two level asymmetric transmission line is coupled via input transmission line **71***a* of interlevel 3 dB coupler **71** to a common level output transmission line **71***b* and to a lower level output transmission line **71***d* which in turn are coupled to asymmetric-symmetric transformer **70** wherein they are transformed to a common level. These common level transmission lines **67***b'*, **71***b'*, **67***d'* and **71***d'* are respectively coupled through element level transformer **16** to antenna elements **72***a*, **72***c*, **72***e* and **72***g*.

Output transmission line **62***b* of symmetric stripline 3 dB coupler **62** is coupled via input transmission line **74***a* to a symmetric stripline 3 dB coupler **74** in the lower deck **14B**, the output ports **74***b* and **74***c* of which are coupled via symmetric-asymmetric stripline transformer **75** to the upper and lower levels of a two level asymmetric stripline of the lower deck **14B**. Transmission line **75***d* at the upper level of the asymmetric stripline is coupled to output transmission line **74***b* and is further coupled through a 45° phase shifter **76** to an interlevel 3 dB coupler **77**, while output transmission line **75***e*, at the upper level of the asymmetric strip transmission line, is coupled to output transmission line **74***c* is further coupled via input transmission line **81***a* to interlevel 3 dB coupler **81**. The output port **77***b* of coupler **77** and the output port **81***b* of coupler **81** are at the upper level of the two level asymmetric stripline while the output ports **77***d* and **81***d* are at the lower level. These output ports are coupled to an asymmetric-symmetric stripline transformer **80** wherein they are transformed to a common level as the center conductors of a symmetric transmission line. The output symmetrical transmission lines **77***b'*, **81***b'*, **77***d'* and **81***d'* respectively couple the output transmission lines **77***b*, **81***b*, **77***d*, and **81***d*, through element transformer **16** to elements **72***b*, **72***d*, **72***f*, and **72***h*. To facilitate the element level transformation, to be described subsequently, the arrangement of the transmission line in the upper deck **14A** and lower deck **14B** at the output end of the respective asymmetrical-symmetrical transformers **70** and **80** is as shown in FIG. **9A**. The spacing between the inner conducting elements at each level is twice the desired element spacing s while the spacing between an inner conductor in deck **14A** and an inner conductor in deck **14B** is substantially equal to the desired element spacing of the array **72**.

It will be recognized by those skilled in the art that a signal coupled to input terminal **61** will traverse the circuitry of FIG. **9** and provide a phase gradient across the array of elements **72***a* through **72***h* that is equal to $\pi/8$. A negative phase gradient of equal magnitude is realized when a signal is coupled to the second input port **91**. This signal will be coupled to a symmetric stripline 3 dB coupler **92**, and via output transmission line **92***a* to a 67½° phase shifter **93** in the lower deck **14B** via the deck level coupler **12**. Simultaneously, a signal of equal amplitude as the signal coupled to a phase shifter **93** but in-phase quadrature therewith is coupled from the output transmission line **92***b* via the deck level coupler **12** to the input transmission line **94***a* of a symmetrical stripline 3 dB coupler **94** in the upper deck **14A**. In deck **14B**, a phase shifted signal from phase shifter **93** is coupled to an input port **95***a* of a symmetrical stripline 3 dB coupler **95**. The output transmission lines **94***c* and **94***b* of 3 dB coupler **94** in deck **14A** and **95***c* and **95***b* of 3 dB coupler **95** in deck **14B** are respectively coupled to upper level input transmission lines **96***a*, **97***a*, **98***a* and **99***a* of 0 dB interlevel couplers **96**, **97**, **98** and **99** via symmetric-asymmetric transformers **102** and **103**. These 0 dB couplers will couple a signal incident thereto at one level of an asymmetrical stripline, as for example transmission line **96***a* at the upper level of deck **14A**, to a transmission line at a second level of an asymmetrical stripline, as for example transmission line **96***b*, with substantially zero attenuation and a phase shift in the order of 90 degrees. Thus, transmission line **96***a* is coupled to the input transmission line **67***c* of interlevel 3 dB coupler **67** via output transmission line **96***b*, accomplishing a level change without the utilization of interlevel pins and soldered connections. Similarly, transmission line **98***a* is coupled via transmission line **98***b* to the input transmission line **77***c* of 3 dB interlevel coupler **77** in deck **14B** and transmission lines **97***a* and **99***a* in the upper level of deck **14A** and deck **14B**, respectively, are coupled via 0 dB interlevel couplers **97**, **99**, transmission lines **97***b*, **99***b*, and 45 degree phase shifters **104**, **105** to the input transmission lines **71***c*, **81***c* of 3 dB interlevel couplers **71** and **81** on decks **14A** and **14B**, respectively. Signals coupled to input transmission lines **67***c*, **71***c*, **77***c* and **81***c* are coupled through interlevel 3 dB couplers **67**, **71**, **77** and **81**, asymmetric-symmetric strip transmission line transformers **70** and **80** and element level transformer **16** to the array elements **72***a* through **72***h*.

Interlevel 3 dB couplers **67**, **71**, **77** and **81** may include two 8.3 dB stripline couplers of the type described by Gunderson and Guida in the Microwave Journal, Volume 8, Number 6, June 1965. A diagram of the inner conductors of this type coupler is shown in FIG. **10**. This type coupler will couple a signal incident to the input transmission line **111** at one level of a two inner level stripline configuration to a common level output transmission line **112** and to a lower level output transmission line **113** with substantially no coupling to the forward direction lower level output transmission line **114**. When a signal with a voltage V_o is incident to transmission line **111** at a frequency for which the coupling length $l=\lambda/4$, this type of coupler, designed for −8.3 dB coupling between transmission lines **111** and **113**, will couple a signal to transmission line **113** that is 0.385 V_o and a signal to transmission line **112** that is 0.923 V_o with a phase angle that is −90° from that of the signal at transmission line **113**. When two such couplers are placed in tandem as shown in FIG. **11** and the length of the interconnecting transmission lines **115** and **116** are properly chosen, a 3 dB coupler is realized between input transmission line **117** and output transmission lines **118** and **119** with the signal phase of the output transmission line **119** in quadrature with the signal phase of transmission lines **117** and **118**. Substantially no signal is coupled to transmission line **120**. In FIGS. **12**, **13**, and **14** are cross-sectional views taken through three sections of 3 dB interlevel coupler of FIG. **11**, FIG. **12** representing the upper level output strip transmission line, FIG. **13** representing the strip lines in the coupling region, and FIG. **14** representing the lower level output strip transmission line. When the material **127** is used for spacing the inner and outer conductors is constructed of a foam dielectric with a dielectric constant substantially equal to 1.03 and the spacings between the upper level inner conductor and the upper ground plane is equal to the spacing between the lower level inner conductor and the lower level ground plane, a 50 ohm system may be realized when the spacing between the two inner conductors s, the spacing between the two ground planes b, and the width of the inner conductors w are in the relationships s/b=0.366 and w/b=1.4.

As stated previously, the desired characteristic of the interlevel 3 dB coupler is the positioning of the output ports at different stripline levels thus allowing lines to cross with minimum coupling therebetween and eliminating all interlevel pin connections normally associated with Butler matrices. To provide complete decoupling between crossing lines, the asymmetrical striplines may be converted to half height asymmetrical striplines by inserting a metallic sheet **130** at the midplane between the ground planes **132***a* and **132***b* as shown in FIGS. **16** and **18** in regions external to the coupling region of FIG. **11**. Referring to FIG. **15**, an upper level asymmetrical stripline with an inner conductor **131**, which corresponds to the upper level strip transmission line **118** of FIG. **12** when excited will establish the field lines **133** and **134** between the ground planes **132***a* and **132***b*, respectively. These field lines form an angle of 90 degrees with all metallic surfaces, as for example, the field line **135** with the ground plane **132***b*. If a metallic surface is inserted at a plane to which the field lines are perpendicular, the over-all system would be unaltered. The insertion of metallic sheets at the mid-plane to which the field lines are not perpendicular, alters the characteristic impedance of the line and generates higher order modes. A similar situation exists with the lower level stripline in FIGS. **17** and **18**. The field lines **136** and **137** created between the asymmetric inner conductor **138** and the ground planes **132***b* and **132***a*, respectively, are disturbed when the metallic sheet **130** is inserted mid-way between the ground planes **132***a* and **131***b*. Thus, the transformation from full size asymmetric stripline to half size asymmetric stripline requires impedance matching and mode suppression. This may be accomplished as shown in FIG. **19** by reducing the inner strip **142** in the half size stripline to be approximately half the width of the inner strip in the full size stripline and providing a reactance **143**, shown as an inductance in FIG. **19**, approximately a quarter wavelength from the junction **144** between the full size and half height asymmetric striplines. To prevent the parallel plate mode from propagating between the asserted metallic ground plane and an original ground plane, as for example, between the ground planes **130** and **132***b* in FIG. **20**, a metallic block **145** which makes good electrical contact with the ground planes **130** and **132***b* is inserted in the half height asymmetrical stripline with one edge substantially coincident with the junction **144**.

To accomplish a 0 dB level change, the 0 dB interlevel coupler may be designed as two interlevel 3 dB couplers, previously described, as shown in FIG. **21**. In this arrangement, a signal with amplitude of V_o coupled to an input transmission line **151** of the first 3 dB interlevel coupler **152** will couple at the junction **153** to the second 3 dB interlevel coupler **154** as a signal with an amplitude of 0.707 V_o in the co-planar output transmission line **155** and as a signal with an amplitude of 0.707 V_o at a phase angle of −90 degrees in the non-planar output transmission line **156**. The signal in the co-planar output transmission line **155** couples across the junction **153** via interlevel 3 dB coupler **154** as a signal with an amplitude of 0.5 V_o at a phase angle of 0 degree to the co-planar transmission line **157** and as a signal with an amplitude of 0.5 V_o at a phase angle of −90 degrees to the non-co-planar output transmission line **158**. Similarly, the signal in the non-planar output transmission line **156** of interlevel 3 dB coupler **152** couples across the junction **153** via interlevel 3 dB coupler **154** to couple a signal with an amplitude of 0.5 V_o at a phase angle of −180 degrees to co-planar output transmission line **157** and a signal with an amplitude of 0.5 V_o at a phase angle of −90 degrees to non-co-planar output transmission line **158**. Thus, the signals at the co-planar output transmission line **157** cancel while a signal with an amplitude of V_o and a phase angle of −90 degrees is coupled to non-planar output transmission line **158** of 3 dB interlevel coupler **154**. As previously discussed, this type of 0 dB interlevel coupler may be employed as an interlevel transformer, asymmetric to symmetric line transformer, and deck level transformer.

For proper operation, the antenna elements **72***a* through **72***h* of FIG. **9** must lie in a common plane. As shown in FIG. **9A**, the output transmission lines of Butler matrix **14** are in two planes, one centered in the upper deck level **14A**, the second centered in the lower deck level **14B**. By means of the element level transformer **16**, these elements may be positioned in a common plane, which may be the common ground plane between the upper deck **14A** and the lower deck **14B**. This element level transformation may be accomplished by providing an array of dipole antenna elements **161** in FIG. **22** which emerge from the common ground plane **162**. This type of element is well known in the art and has been described by J. E. Boyns and R. Grannini, et al each at the Array Antenna Conference NELC, San Diego, Calif. in February 1972. Coupling to this dipole may be accomplished by eliminating the lower ground plane for the lower deck **14B** or the upper ground plane for the upper deck **14A** for a distance from the edge **161***a* of the array to at least beyond the base **161***b* of the dipole element configuration, thus providing a dielectric **163** with an unclad region **164** and a copper clad region **165**, as shown in FIG. **23**. The center conductors of the deck output transmission lines are etched to form a loop **166** which is a printed circuit balum, such as that described by Bawer et al, in IRE Transactions on Microwave Theory and Techniques, Volume MTT-8, No. 3, May 1960. This balum positioned across the narrow gap **167** for coupling to the desired dipole. Thus the entire array is formed in the common ground plane between the upper and lower decks **14A** and **14B**, respectively, by etching an array of dipoles therein, alternately exciting these diipoles from each side by balums formed from the center stripline of the upper and lower decks and terminating the upper and lower ground planes of the decks **14A** and **14B**, respectively, at a desired distance from the edge of the array.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than limitation and that changes may be made within the purview of the appended claims without departing from the true scope and spirit of the invention in its broader aspects.

We claim:

1. An apparatus having a multiplicity of co-planar input ports numbering n and a plurality of co-planar output terminals numbering m wherein each of the n input ports are coupled to all of the m output terminals such that an excitation coupled to one of the input ports causes responsive excitation at each output terminal in a manner to establish a phase and amplitude distribution across the m output terminals that is associated with the excited input port comprising:

a power divider arranged to couple each of said n input ports to at least two non-planar output ports; and

a matrix having input ports on at least two decks each coupled to one of said power divider output ports and output ports coupled to said m output terminals, each deck having sections thereof which include conductors on at least two levels with crossing conductors located at different levels and wherein transitions between levels are accomplished through non-contacting interlevel elements positioned in an electromagnetic coupling relationship.

2. An apparatus in accordance with claim **1** interlevel coupling elements include interlevel power dividers each having a section on a first level electromagnetically coupled to a section on a second level, said first section having first and second ports and said second section having third and fourth ports, said interlevel power dividers constructed and arranged to divide a signal incident to said first port between said second and third ports with said fourth port substantially decoupled from said first port.

3. An apparatus in accordance with claim **2** wherein said interlevel coupling elements include interlevel couplers, each having a first section on a first level in non-contacting electromagnetically coupling relationship with a second section on a second level, said first section having first and second ports and said section having third and fourth ports, each interlevel coupler constructed and arranged to couple signals between said first and third ports with said first and third ports substantially decoupled from said second and fourth ports.

4. An apparatus in accordance with claims **1**, **2**, or **3** wherein said matrix includes sections comprising first and second ground planes having three sections therebetween, a middle section and two outer sections, a first level determined by a plane at a boundary between said middle section and one of said outer sections, a second level determined by a plane at a boundary between said middle section and an outer section other than said one, and two level asymmetrical striplines having inner conductors positioned at said first and second levels.

5. An apparatus in accordance with claim **4** wherein said matrix further includes half height asymmetric stripline formed in preselected locations by positioning a metallic sheet substantially equidistant between said first and second ground planes.

6. An apparatus in accordance with claim **5** wherein said matrix further includes metallic blocks positioned at preselected locations in electrical contact with said equidistant metallic sheet and one of said first and second ground planes for suppressing parallel plate modes.

7. An apparatus in accordance with claim **6** further including an array of co-planar antenna elements and element level transformers coupled between said matrix and said co-planar elements for transforming said conductors at said first and second levels to a common level for respectively coupling to said co-planar elements.

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